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A Look at the Benefits of Post-processed Differential GPS

by

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Table of Contents

Introduction 2
What is DGPS? 2
What is Real-time DGPS? 2
What is Post-processed DGPS? 2
When to Use Real-time vs. Post-processed 3
Some Real World Data 3
    The Dynamic Data 4
    The Static Data 6

List of Figures

Figure 1 GPS Vehicle Track 4
Figure 2 Lawrence Expwy Exit 4
Figure 3 Shoreline / Middlefield Intersection Uncorrected GPS 5
Figure 4 Shoreline / Middlefield Intersection Differentially Corrected GPS 6
Figure 5 Uncorrected Static GPS 7
Figure 6 Differentially Corrected Static GPS 7

Introduction

The Pacific Marine Geology (PMG) Branch of the US. Geological Survey has been a marine Global Positioning System (GPS) user since the early 1980's. In 1992, we began to increase our GPS positioning by implementing a real-time differential GPS (DGPS) system. This paper describes the need and benefits of further expanding our DGPS arsenal to include post-processed as well as real-time differential GPS.

What is DGPS?

GPS is a highly accurate satellite positioning system that even though widely used is still experimental and subject to the controls of its developer the US Air Force. There are a number of factors including atmospheric interference, multipath signals, satellite ephemeris errors, satellite clock errors and selective availability (SA) that degrade the GPS positions provided by a single autonomous GPS receiver. The Air Force states the nominal horizontal accuracy of GPS to be 100 meters. In fact, the Air Force actively degrades the accuracy of GPS through its program called Selective Availability which causes dithering of the onboard satellite clocks. Differential GPS will remove errors that are common to both the base and roving GPS receivers including SA.

Differential GPS requires two GPS receivers to be operating at the same time. One receiver must be stationary at a known location, let's call it the base station. The base station must collect GPS satellite data for all satellites within its view. Since the location of the base station is known very accurately, the base station can compute what the correct GPS pseudoranges should be if there were no system or SA errors. Pseudoranges are the key satellite observation in computing a GPS position i.e. the distance from the receiver antenna to the satellite antenna plus the clock offset.

Now for the second GPS receiver, let's call it the rover. The rover may be stationary or dynamic. The rover is only constrained to operate within about 300 miles of the base station to obtain the best results. The base and the rover need to be looking through about the same piece of atmosphere so that the atmospheric corrections made at the base will be valid for the atmosphere over the rover. If the rover and the base are really far apart they will each see a different constellation of satellites. As long as the rover is tracking a subset of the satellites that the base station is tracking, differential corrections are possible.

What is Real-time DGPS?

If the DGPS system is a so-called real-time system, then the base station will compute, format and transmit the corrections usually through some sort of data link e.g. VHF radio or cellular telephone with each new GPS observation. The Radio Technical Commission for Maritime Services (RTCM) has developed a standard differential GPS correction format that allows GPS receivers from one vendor to receive differential corrections that were generated by equipment from another vendor. This format is known as RTCM-104. Most GPS equipment vendors support this format for real-time broadcast of GPS corrections. DGPS corrections are typically transmitted between 5-15 seconds for marine survey applications. The rover system requires some sort of data link receiving equipment to receive the transmitted differential GPS corrections and get them into the to GPS receiver. The roving GPS receiver can then apply the differential corrections to its current observations to improve its computed position.

What is Post-processed DGPS?

In post-processed differential GPS the base and roving receivers have no active data link between them. The base and roving GPS systems record the satellite observations that will allow differential corrections to occur at a later time. The base station must record all the satellite ephemeris, ionospheric, measurement and satellite constellation data since it does not know which constellation the roving receiver may be using. The roving receiver must record position, constellation and issue of ephemeris information. These recordings typically involve a computer at both the base and roving sites. Most vendors will sell differential correction software that will work with data collected from their receivers.

When to Use Real-time vs. Post-processed.

The biggest difference between real-time and post-processed DGPS is that real-time DGPS tells you where you **are** and post-processed DGPS tells you where you **were**. There are some serious logistical differences between the two methods that should be noted. With real-time GPS you can get the DGPS accuracies in the present moment but only if you can maintain the real-time data link with the base station. Since VHF and cellular phone have fairly short ranges of operation offshore, this can pose a serious problem to the real-time user. VHF is susceptible to RF interference in congested urban areas. Real-time DGPS requires the extra hardware expense, support and logistics in the field and on the rover. Radio equipment is often sensitive to the elements and vandals. With real-time DGPS, the rover has only one shot at correcting the current position computation. If a blunder occurred at the base station site, say the reference position of the base station unit was incorrectly entered, all of the positions at the rover would be errantly offset, with no means of correction. Finally, with our current real-time equipment, if the real-time data link is lost, the differential accuracy is gone for good. There is no way to post-process the rover data that was recorded using our real-time GPS system. Therefore real-time DGPS should be used when the operation requires the 2-5 meter sort of accuracy in real-time and the data link is known to be reliable in the given operations area. Transponder deployment and recovery, reoccupation of previous sampling sites and other high precision navigation operations are good candidates for real-time DGPS.

Post-processed DGPS has its own set of limitations as well. Post-processed DGPS will require a logging computer at both the base and remote sites. There will need to be either a fairly large hard drive to support data recording over long operations or else a support person that can change removable logging media. The rover system will also require logging media and will become another task for the watchstanders. Follow-up processing, while fairly painless, will be required post cruise. Post-processed DGPS has one clear advantage over real-time DGPS. This advantage lies in the ability to change the reference position of the base station post-cruise. This means that even if the reference position is entered incorrectly all of the real-time data recorded on the rover will still be correctable with post-processing. For these reasons post-processed differential GPS is best suited to operations where a base station can be set up in a field support office that is manned on a daily basis, or for extended day only operations where the cruise staff can download the base station data on a daily basis.

In summary, the best possible solution is to use both systems whenever real-time DGPS is required. When high accuracy DGPS is required, use the real-time system **and** the post-processed recording system. The post-processed backup system will provide a means of achieving DGPS accuracies for the entire operation even if the DGPS data link is periodically or totally lost.

Some Real World Data

All of these discussions are great but let's look at some real data to actually see what a difference differential correction can make. Two different types of data will be presented here; dynamic and static. The dynamic data set was obtained by mounting a GPS receiver on top of a truck and driving from a residence in Mountain View, CA to Highway 101 and back as shown in Figure 1. The differential corrections were done using the post-processing mode described above. A notebook computer in the truck recorded the rover GPS data. A second computer recorded the base station data at the Mountain View residence. The static data presented is the base station data before and after differential corrections.

The Dynamic Data

Figure 1 shows the entire coverage of both the uncorrected and post-processed differentially corrected GPS data, however at this scale it is difficult to see much difference between the two. The dotted box lines show the two areas that will be examined at a finer scale.

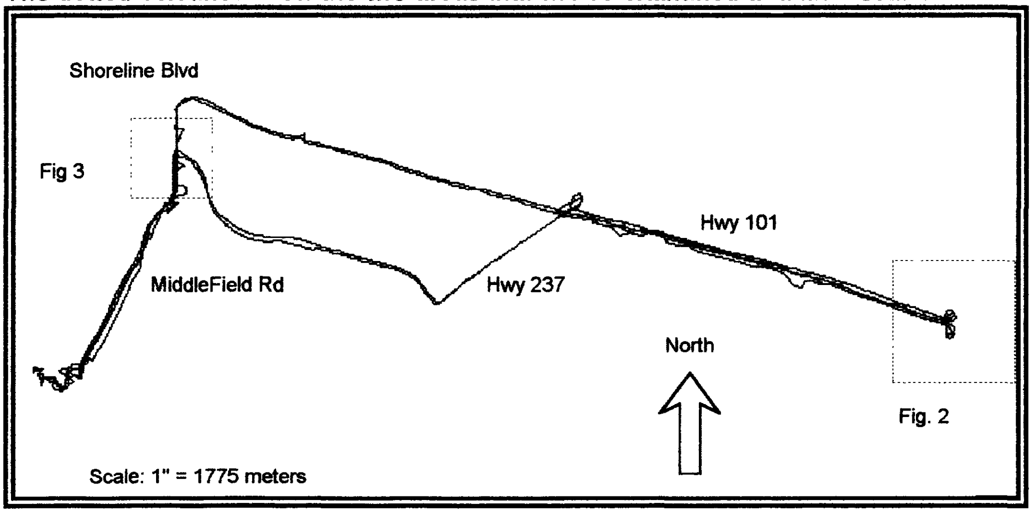

Figure 1. GPS Vehicle Track

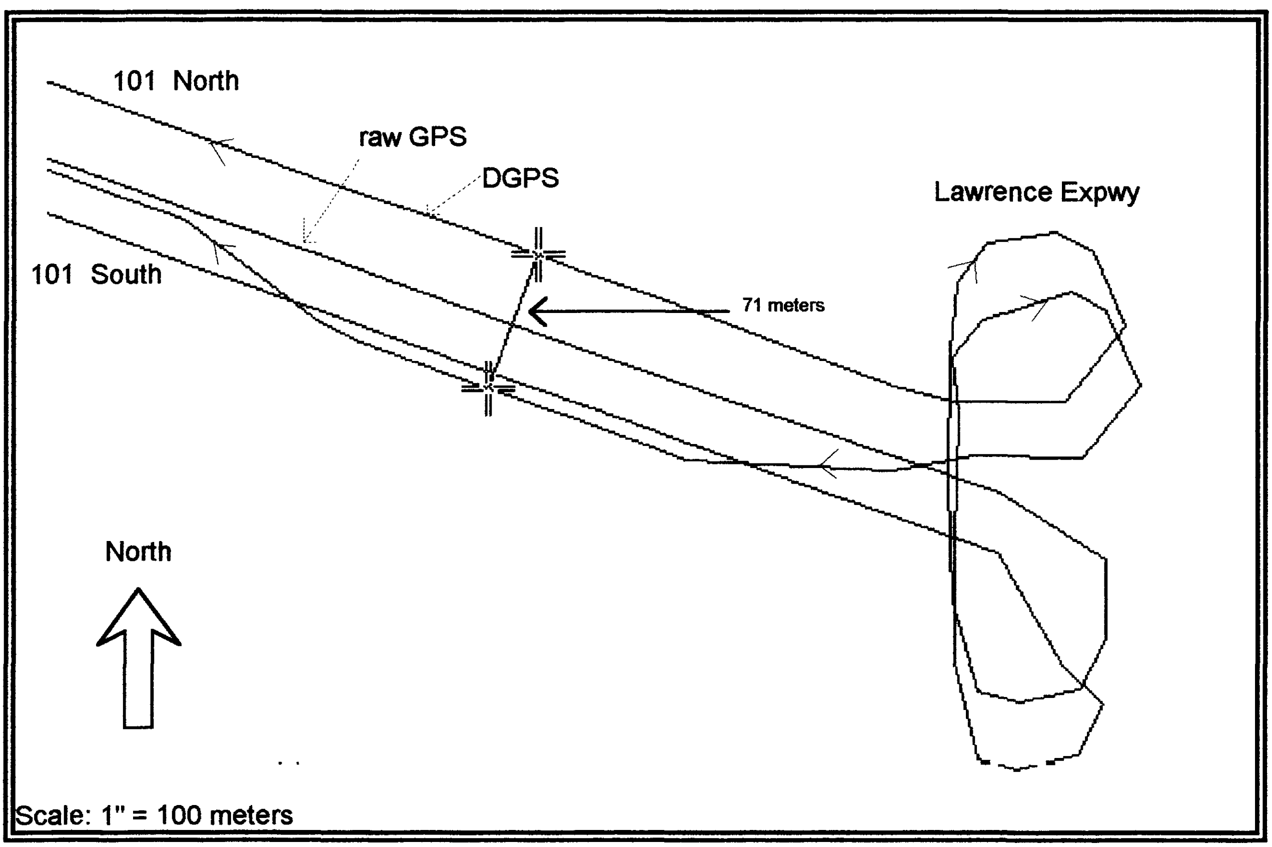

Figure 2. Lawrence Expwy Exit

Figure 2 shows the corrected and uncorrected data sets as the truck was heading south on Highway 101 and exited on the Lawrence Expressway exit and then reentered Highway 101 northbound. The raw data set is consistently and errantly offset to the south by about 30 meters.

The two cross marks denote a rather large excursion in the position data that was removed with differential correction. The magnitude of this particular excursion was about 71 meters.

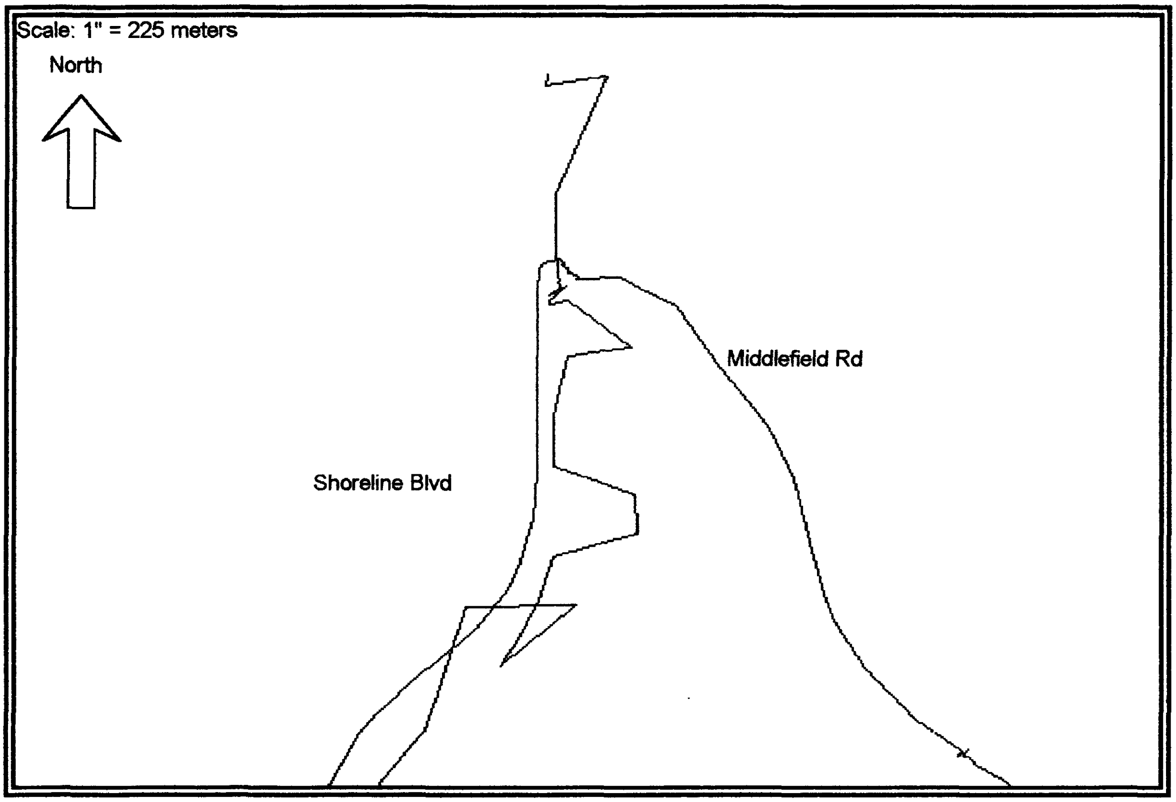

Figure 3. Shoreline / Middlefield Intersection Uncorrected GPS

Figure 3 above shows the blow-up of the uncorrected GPS data as the truck was returning on Middlefield Road and turned left on Shoreline Blvd. (heading west). Note the 40 meter jumps in position in the northbound section of Shoreline Blvd.

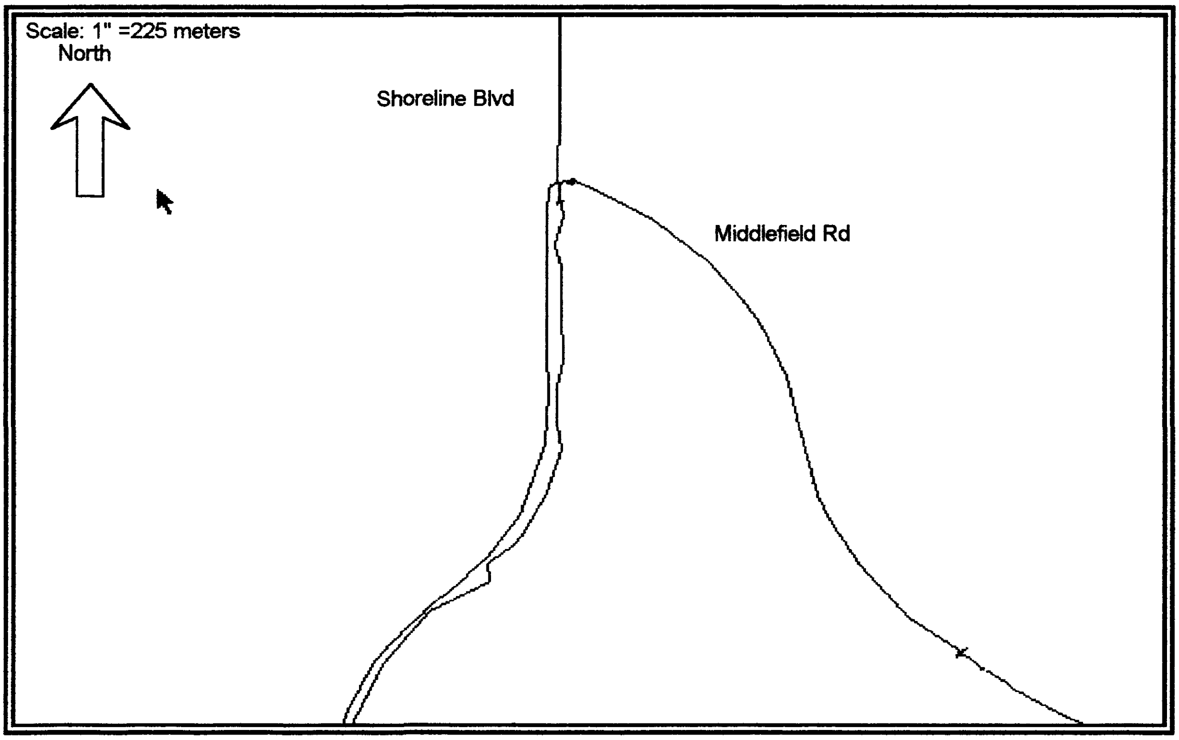

Figure 4. Shoreline / Middlefield Intersection Differentially Corrected GPS

Here is the same section as shown in the previous figure with the differentially corrected data Note how the 40 meter excursions have been removed.

The Static Data

Following are two scatter plots of uncorrected GPS data recorded at the base site and the post-processed differentially corrected version of the same file. Figure 5 shows a scatter plot of an uncorrected base station file.

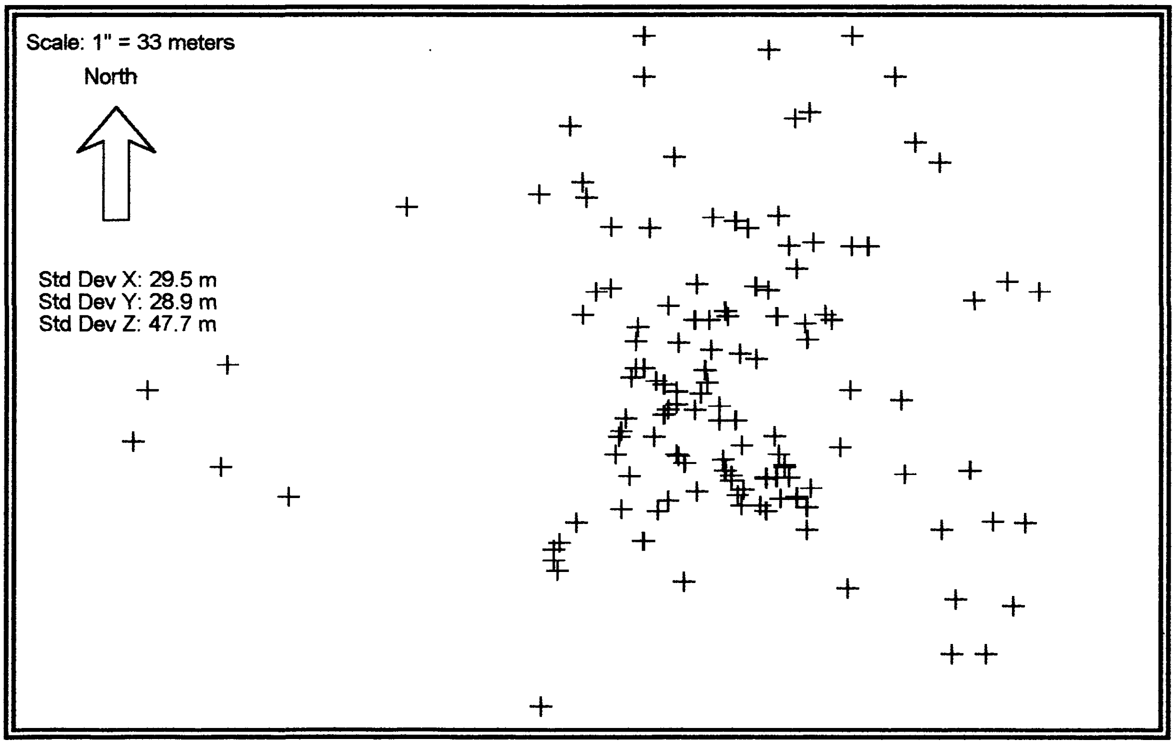

Figure 5. Uncorrected Static GPS

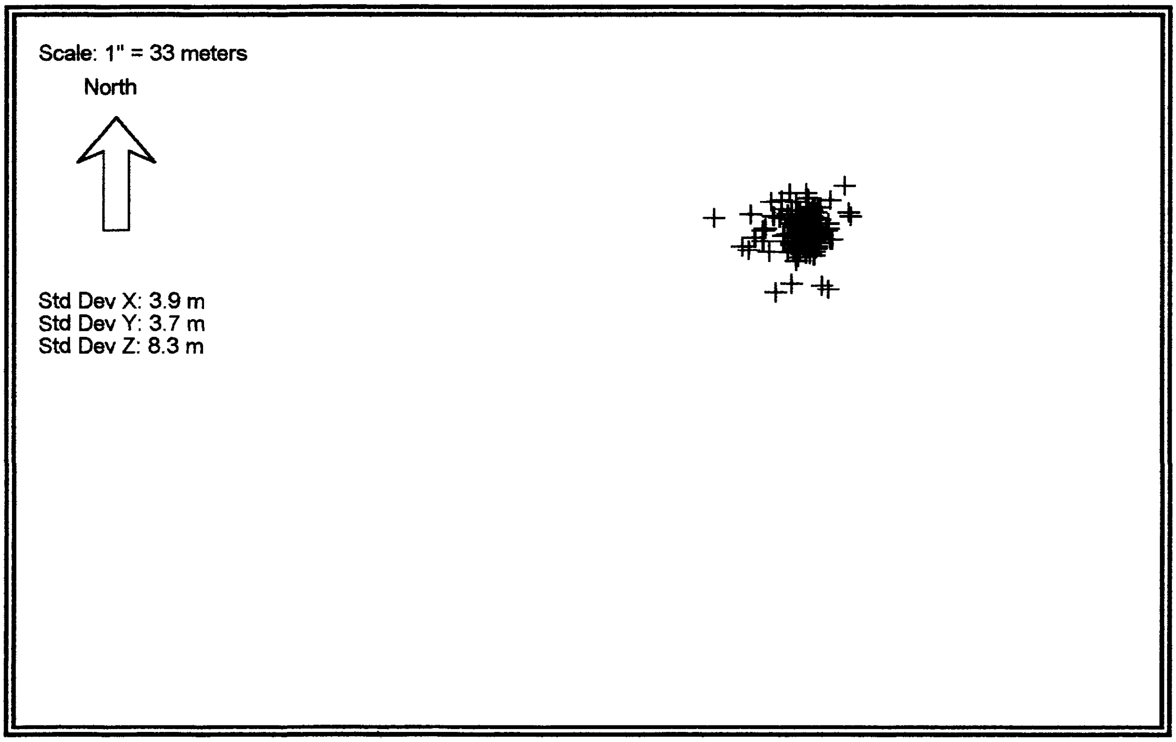

Figure 6. Differentially Corrected Static GPS

Figure 6 above shows the base station file after it has been differentially corrected by post-processing it against itself.