Ionospheric Effects on GPS Surveying

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Introduction

The use of global positioning system (GPS) satellites has revolutionized commercial surveying over the last 10 to 15 years. It is now possible to obtain three-dimensional positions more rapidly, precisely and inexpensively than before. Small differences in the arrival time of the satellite signals as different receivers lead to precise determinations of the distances between receivers. The propagation speed of electromagnetic waves is altered by the presence of free electrons in the ionosphere. Most of the effects of the ionosphere are eliminated by using signals broadcast at two different frequencies and correcting for dispersion. Residual effects occur since the two different signals do not follow identical ray paths. One specific example will be given below of residual ionospheric effects.

Reference Positions

The National Geodetic Survey manages a network of continuously operating reference stations (CORS). Several different government, academic, commercial and private organizations contribute to this network. A subset of 30 (out of 153) sites have been used to derive high precision reference positions. First relative baselines are found. Then these are obtained into adjusted positions for all stations (with two stations fixed). Daily variations in these positions will be used to test for possible ionospheric effects.

Specific Measurements

Two south Texas sites were selected for detailed study. At mid-latitudes, most ionospheric effects increase in going from north to south. Figure One shows results for the Corpus Christi site operated by the U.S. Coast Guard. This is operated for 24 hours per day. Measurements were made during the period March 2, 1998 to January 30, 1999. Of the 335, possible days solutions were actually carried out for 290 days. The amplitude of the three-dimensional vector difference between the daily position and the reference position in millimeters is plotted versus Ap. Although Ap is derived from the variation of repeated earth-based measurements of the geomagnetic field, its physical origin is in electric currents in the ionosphere. It is used here as a measure of the disruption in the ionospheric over a 24 UT day. The dotted curve is a least squares fit. Although slightly positive, it is not sadistically significant and fits only .02% of the variance. The extensive averaging has essentially eliminated all discernable ionospheric effects.

GPS position accuracy

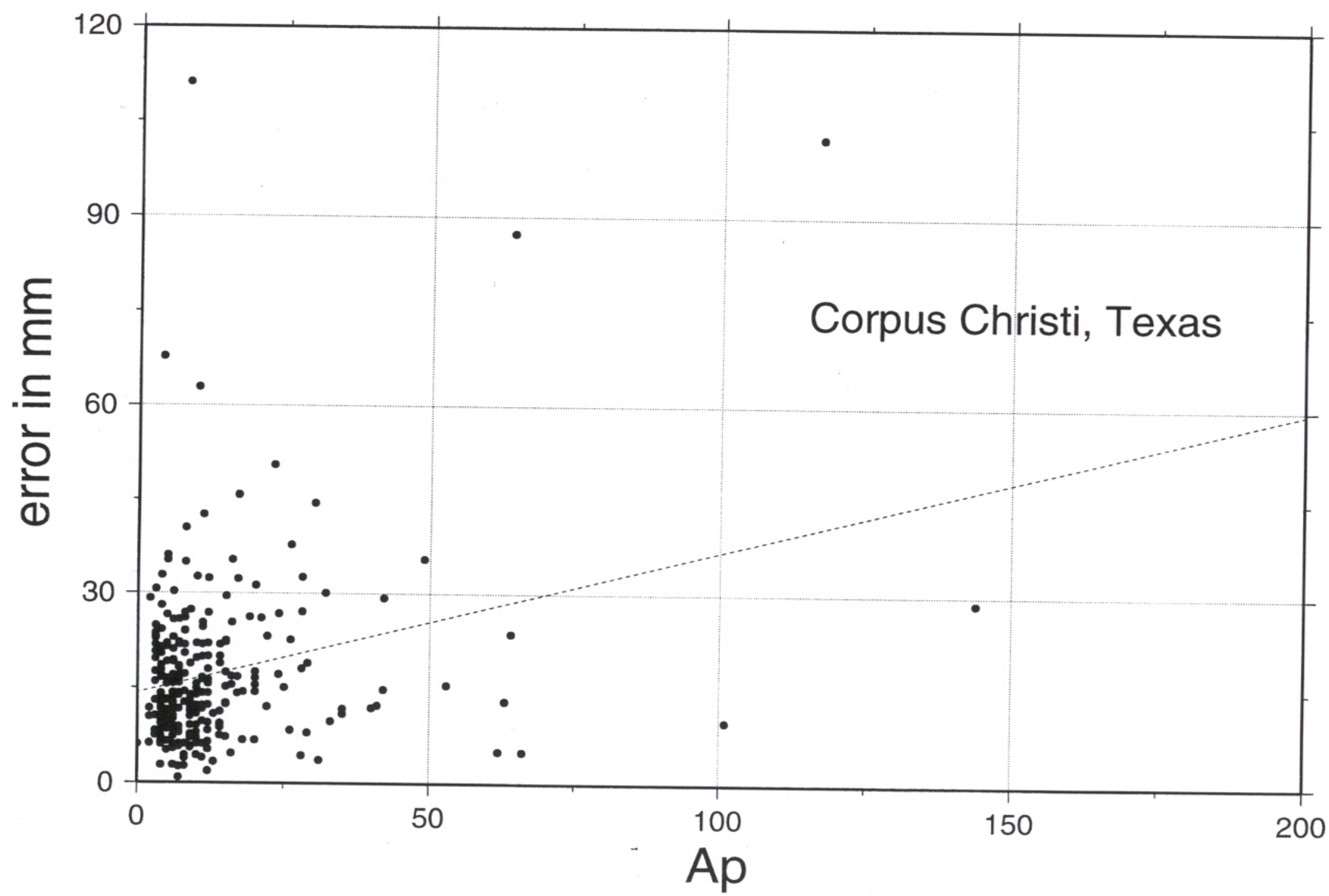

Figure Two shows similar results for Arkansas Pass about 15 kilometers away. This site, belonging to the Texas Department of Transportation, is operated only 11 hours per day, mostly during the daylight hours. In this case 282 days of the possible 335 were used. There is a modest increase in the mean error from 12 to 14 millimeters. The outliers show a larger scatter and some tendency to align in a lower left to upper right fashion. The dotted line is a least squares fit. In this case the slope is about an order of magnitude larger and is statistically significant at greater than the 99.9 % confidence level, fitting about 7-1/2% of the variance. Here, even though there is extensive averaging a moderate residual error due to ionospheric effects is evident.

Summary and Future Plans

Evidence of a residual ionospheric effect of the ionosphere on the accuracy of GPS surveying has been shown. Work is underway on shorter duration position determinations, closer to that used in standard commercial practice, where ionospheric effects may be more severe.

Acknowledgment

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