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Sub-millimeter Signal Detection Using Continuous GPS: Cross Validation Using GIPSY and GAMIT Solutions for the Yucca Mountain Network

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A continuous and densely spaced GPS network has been installed at Yucca Mountain, southern Nevada, as part of the BARGEN array. It was funded by the Department of Energy to characterize strain at the proposed nuclear waste repository. Each GPS antenna is deep-mounted into solid bedrock and atmospheric effects in the desert climate of the region are relatively low, making this an ideal network to explore the potential precision of GPS. Due to the importance of obtaining an accurate and reliable set of velocity measurements at Yucca Mountain, two separate groups using entirely different methods have independently processed the GPS data from this network. The UNR group has utilized JPL's GIPSY-OASIS II, employing a precise point positioning technique, whereas the CfA group has used MIT's GAMIT software and a double-differencing approach. Comparison of the two sets of results for 28 stations and 2.8 years of data has revealed only small differences in horizontal velocity estimates, with formal errors for both groups less than 0.17 mm/yr and an RMS of residual velocity differences of 0.23 mm/yr. The two solutions are consistent with one another at the two sigma level. Relative horizontal velocities at stations within 40 km of Yucca Mountain itself are on the order of $<$0.5 mm/yr, with a smooth pattern of NNW shear. In order to obtain negligible differences in results both groups had to account for coseismic offsets caused by the 1999 Hector Mine earthquake. It was also necessary to perform ambiguity resolution in GIPSY. Without ambiguity resolution, the GIPSY results were significantly different to those produced by GAMIT. The data was processed in GIPSY on a line-by-line basis, relative to a station in the center of the Yucca Mountain network, to produce a regionally-referenced solution free of common mode signals. It was evident in both solutions that radome changes produce a measurable effect in the vertical component, giving an apparent vertical swell of approximately 2 mm/yr in the Yucca Mountain region if left unaccounted for. With the radome effect removed, vertical velocities within 40 km of Yucca Mountain are minimal, with an RMS of 0.56 mm/yr, which also suggests a high degree of precision. This study has not only given us a high degree of confidence in our estimated velocities for the Yucca Mountain area, but also indicates a measure of the success of both GIPSY and GAMIT. We have shown that solutions produced through these different GPS processing packages, each containing over 1 million lines of code, can produce accurate and virtually identical results at the level of $<$0.5 mm/yr,

and have demonstrated that it is possible to confidently detect sub-millimeter per year signals over an approximately 200 km wide area using GPS.