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# Three Component Borehole Strain Measurement in western Taiwan

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The Central Geological Survey of Taiwan has deployed ten Gladwin Tensor Strainmeters in the western foothills of the island since 2003, as part of its intensified active fault-monitoring program following the Chi-chi Earthquake. The instruments installed are also intended to supplement the earthquake-monitoring and crustal deformation observations from the arrays of CGPS, seismometers and InSAR as part of a more systematic program for the observation of plate boundary tectonics of this region. The GTSM array is to be supplemented by an additional set of four sites surrounding the Taipei city, the capital of Taiwan with a population of over six million, by the end of 2008.

The strain instrument configuration consists of five independent modules with each component 170 mm in length. Four of these measure strain at different orientations in a plane perpendicular to the axis of the borehole. A further component measures the orientation of the instrument in the hole using a magneto-resistive sensor. The outer diameter for all modules is a nominal 100 mm. The instruments were installed in expansive grout in 140 mm diameter boreholes approximately 200m deep at levels determined from cores. Strain is monitored using the radial component of deformation of the instrument diameter. The relative position of the central moving plate of the sensing transducers can easily be monitored to a few picometers. The three primary strain cells are configured at 120 degrees from each other, and the final cell is a redundant one. Data recorded on site at 100Hz, 20Hz, 1Hz and 10 minutes sampling rates is available remotely from the instruments via ADSL, modem and radio.

Actual instrument displacements can be represented, in terms of vectors and matrices,

by U=M.G.H.T.S. Where U is the deformation vector consisting of the three gauge deformations; M is the gauge multiplier matrix which allows for the mechanical differences for each gauge; G is a direction matrix incorporating the instrument element orientations; H is the coupling matrix consisting of the areal and shear strain coupling factors; T is a matrix describing local topographic and geological influences; S is the regional strain state at the measurement site, which is the object of the measurement. The raw data since installation are dominated by the grout and hole recovery processes which are characterized by separable exponential decays. The short exponential is the grout curing, and the longer exponential is associated with recovery of the pre-existing earth stresses in the borehole material which were relieved very locally at drilling. The modeled exponentials can be removed from raw records to produce geophysically useful residual signals for tectonic studies. The earth tidal signals useful for in-situ calibration of the system response are clearly seen in all channels at each site. The multiple event, offset event, after-slip event and slow event are not rarely seen in the high-frequency records associated with local/remote events. GTSM measures strain with a dynamic range of at least $10^{-4}$, and are essentially flat to DC, so that they can directly provide displacement data not commonly available for analysis. It is expected that these data will contribute to a better understanding of dynamic rupture effects, and earthquake source mechanisms.