Title: The Tokachi-Oki Earthquake: Evaluation of GPS as a Strong Motion Instrument
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The goal of this proposal is to assess how well GPS can serve as a strong-motion instrument. Although GPS receivers do not have the dynamic range of seismic instrumentation, they do not clip and are intrinsically sensitive to position. GPS is not a replacement for seismic instrumentation, but we believe it might be possible to combine seismic and geodetic observations to improve measurements in the near-field of large earthquakes. To test our hypothesis, we are analyzing 1-Hz GPS data recorded during the 2003 Tokachi-Oki earthquake by the Geodetic Survey Institute GPS network in Japan. These GPS observations can be combined with hundreds of strong motion records, thus providing a very broadband displacement time history that can be used by a) geophysicists who model the rupture and b) earthquake engineers who need to understand ground shaking to build safer structures.

We have identified 5 tasks for this grant: estimate static seismic offsets; estimate 1-Hz GPS positions for all sites; retrieve strong motion records; make preliminary comparisons of GPS and strong motion records; and develop software to integrate seismic records with GPS

Results

Static seismic offsets have been computed for all available data. In Table 1 we list horizontal and vertical static offsets for all sites with east displacements larger than 2 cm. One-Hz sites have also been analayzed. Seismic data have been downloaded, with an emphasis on collocated sites (see Figure 1). Preliminary comparisons have been completed for several dozen sites. A representative geodetic-seismic comparison is shown in Figure 2. We have established that there are significant seismic sensor orientation errors. Gordon Emore and Jennifer Haase have written code that double integrates these records, allowing an orientation error to be estimated. Either 1-Hz or 30 second GPS estimates can be used as a constraint.

Non-technical Summary

Preliminary analysis shows that GPS can be used as an accurate sensor of displacement for very large earthquakes. Current records are limited to 1 sample/second but should be extended to higher frequencies and other earthquakes.

Reports
No reports have published at this time. Gordon Emore plans to show these results at the Fall 2005 AGU Meeting. A paper to be submitted to BSSA is in progress.

Data
Seismic data used in this work are publicly available from Knet and KiKnet. The GPS data are available from GSI. Final processed seismic and geodetic records will be archived at the completion of the project.

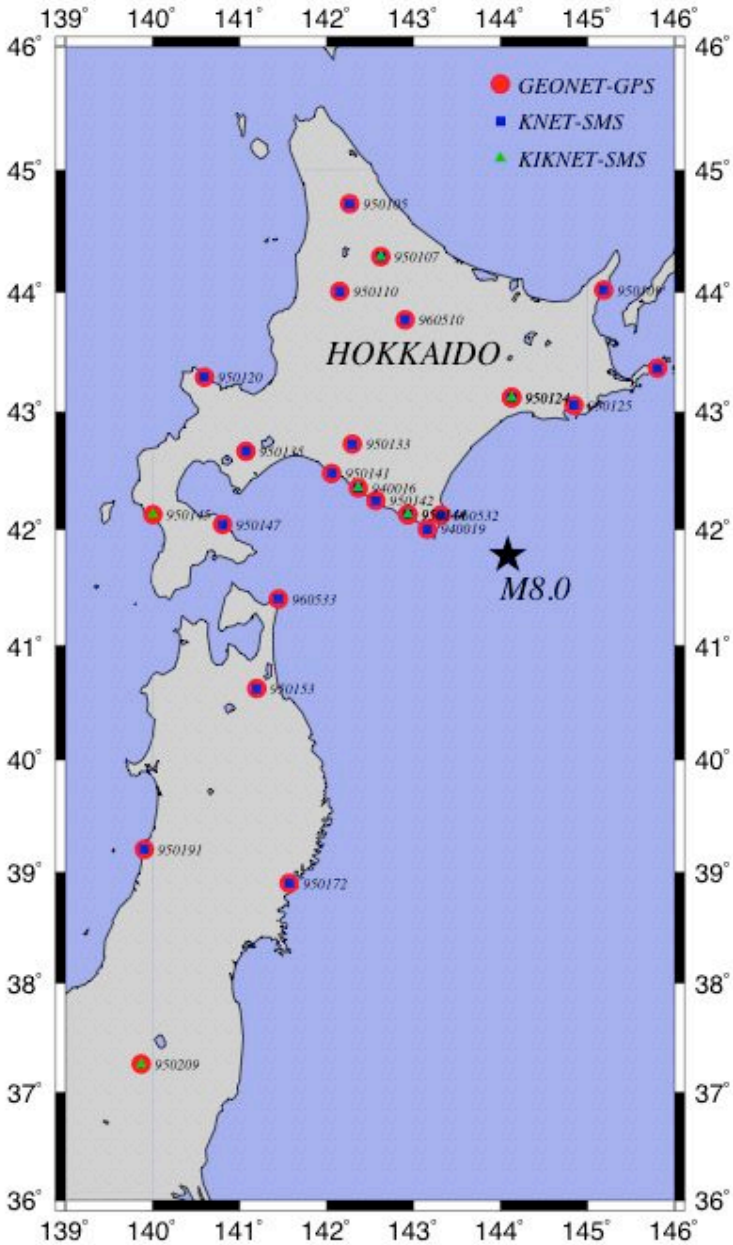

Figure 1. Map of collocated seismometers (KiK and Knets) and 1-Hz GPS sites (GEONET). This figure was produced by Gordon Emore at Purdue University.

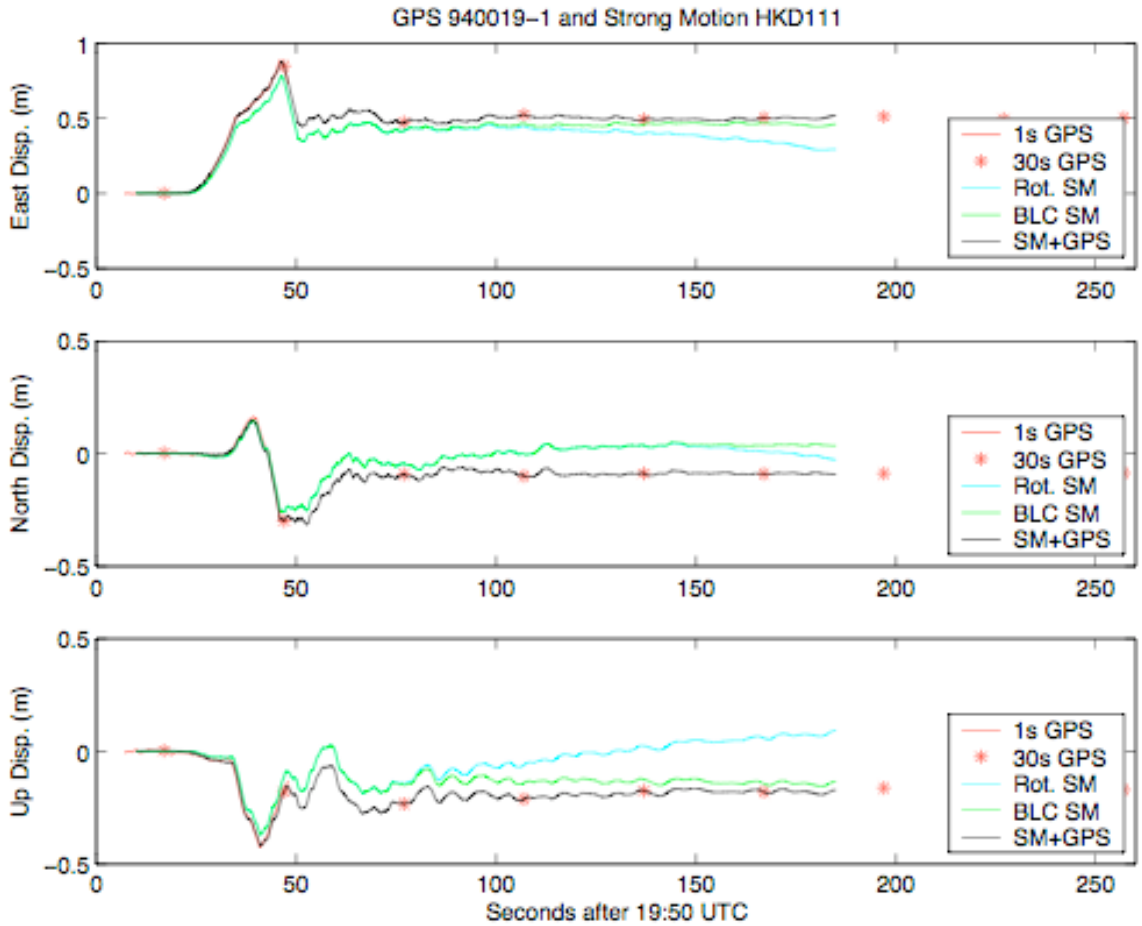

Figure 2. Colocated strong motion (HKD111) and high-rate GPS(940019). Both 1-Hz and 30 second GPS solutions are shown. The 1-Hz telemetry stream was lost at this site, but the 30-second data were held on disk for later retrieval. They are used to constrain the double integration of the seismic sensors (in black). BLC is a baseline correction. Seismic data are rotated to accommodate sensor orientation errors. This figure was produced by Gordon Emore and Jennifer Haase (Purdue University).

Table 1 (Static offsets and uncertainties in cm)

Site	E	+-Esig	N	+-Nsig	V	+-Vsig
0003	+3.04	+-0.74	-5.55	+-1.40	+0.83	+-1.36
0005	+3.02	+-0.69	-3.03	+-0.99	-0.55	+-0.81
0006	+4.33	+-0.56	+3.15	+-0.83	+1.18	+-1.38
0007	+9.01	+-0.50	-14.48	+-0.81	-0.09	+-1.26
0008	+5.81	+-0.52	-6.29	+-0.74	+0.94	+-1.13
0009	+9.93	+-0.56	+8.29	+-0.69	+4.10	+-1.09
0010	+14.75	+-0.89	+7.74	+-0.96	+4.58	+-2.15
0011	+20.79	+-0.60	-33.25	+-0.69	-9.09	+-1.64
0012	+23.11	+-0.66	-20.00	+-0.70	-2.25	+-1.36
0013	+5.36	+-0.77	-4.19	+-0.76	-0.29	+-2.82
0014	+11.10	+-0.40	-8.35	+-0.87	+2.03	+-1.47
0015	+75.81	+-0.73	-48.34	+-0.79	-22.15	+-1.49
0016	+28.22	+-0.61	-9.36	+-0.56	-4.89	+-1.25
0017	+2.09	+-0.65	-1.45	+-0.44	+0.69	+-1.51
0018	+4.99	+-0.52	-1.73	+-0.74	+0.88	+-1.38
0019	+50.09	+-0.72	-10.19	+-0.75	-16.11	+-1.19
0105	+2.04	+-0.37	-4.84	+-0.79	+0.84	+-1.05
0106	+2.67	+-0.84	-3.89	+-1.28	+1.72	+-1.24
0107	+3.09	+-0.57	-6.87	+-1.22	+1.80	+-1.61
0109	+2.46	+-0.78	+0.23	+-1.16	+0.69	+-1.89
0110	+5.29	+-0.43	-7.74	+-0.88	+1.25	+-1.34
0111	+3.06	+-0.63	-8.29	+-0.79	+0.46	+-1.01
0112	+21.47	+-0.64	-15.68	+-0.76	-4.32	+-1.49
0113	+3.02	+-0.72	+2.20	+-0.96	+1.38	+-1.28
0114	+2.39	+-0.52	-8.46	+-0.71	+0.77	+-1.33
0115	+2.99	+-0.66	+1.28	+-0.86	+1.73	+-1.32
0116	+4.05	+-0.79	+2.22	+-0.96	+1.01	+-1.37
0117	+6.03	+-0.63	-6.92	+-0.78	+10.76	+-1.71
0118	+5.56	+-0.88	+4.35	+-1.16	+1.60	+-2.05
0119	+3.84	+-0.50	+2.57	+-0.84	+1.81	+-1.47
0120	+4.63	+-0.47	-3.51	+-1.15	+1.53	+-2.10
0121	+9.98	+-0.34	-20.68	+-0.58	-3.99	+-0.87
0122	+6.73	+-0.75	-3.77	+-0.89	-0.12	+-1.26
0123	+14.86	+-0.45	-25.11	+-0.75	-3.20	+-1.22
0124	+10.25	+-0.82	-9.55	+-0.81	-0.88	+-1.29
0125	+11.85	+-0.52	+10.09	+-0.66	+5.90	+-1.26
0126	+3.97	+-0.55	-2.63	+-0.78	+1.36	+-1.43
0127	+4.57	+-1.00	-2.37	+-1.64	+0.82	+-2.29
0128	+8.90	+-0.77	-4.64	+-1.03	+2.83	+-2.07
0129	+4.88	+-0.90	-1.26	+-0.83	+1.73	+-2.30
0130	+4.11	+-0.53	-1.71	+-0.58	+1.30	+-1.01
0131	+2.59	+-0.63	-2.17	+-0.78	+1.26	+-1.90
0132	+14.47	+-0.94	-7.83	+-0.73	-0.85	+-1.96
0133	+26.82	+-0.53	-16.75	+-0.94	-3.15	+-1.46
0134	+48.12	+-0.54	-43.92	+-0.70	-19.16	+-1.97
0135	+7.12	+-0.72	-2.10	+-0.96	+2.34	+-1.41

0136	+10.03	+-0.77	-4.47	+-0.92	+1.64	+-1.35
0137	+5.10	+-0.77	-1.76	+-0.84	+0.74	+-1.28
0138	+56.41	+-0.52	-45.31	+-0.65	-16.03	+-1.48
0139	+7.63	+-0.79	-3.29	+-1.04	+1.95	+-2.06
0140	+3.16	+-0.55	-1.87	+-0.76	+1.34	+-0.93
0141	+17.97	+-0.58	-7.69	+-1.00	-2.45	+-1.21
0142	+35.96	+-0.67	-8.61	+-0.73	-10.31	+-1.69
0143	+2.05	+-0.68	-1.86	+-0.69	+1.83	+-1.68
0144	+51.53	+-0.68	-11.38	+-1.10	-16.83	+-2.47
0146	+3.15	+-0.60	-1.42	+-0.80	+1.61	+-0.94
0147	+2.94	+-0.39	-2.43	+-1.17	+2.62	+-1.14
0148	+2.73	+-0.62	-0.16	+-0.96	+1.24	+-1.88
0504	+3.66	+-0.66	-7.55	+-0.98	+2.40	+-1.57
0506	+5.82	+-0.57	-9.81	+-0.78	+1.26	+-1.26
0508	+7.78	+-0.44	-10.71	+-0.99	-0.11	+-1.22
0509	+6.48	+-0.67	-7.59	+-0.83	+0.89	+-1.37
0510	+6.12	+-0.43	-11.45	+-1.16	+0.62	+-1.40
0511	+4.00	+-0.59	-13.32	+-0.83	+0.37	+-1.54
0512	+6.25	+-0.61	+5.15	+-0.62	+0.94	+-1.29
0513	+4.89	+-0.56	-8.76	+-0.69	+0.32	+-1.42
0514	+13.93	+-0.54	-17.11	+-0.79	-0.77	+-1.35
0515	+4.63	+-1.04	+1.22	+-0.82	+0.28	+-1.55
0516	+11.15	+-0.57	-8.48	+-0.69	+2.62	+-1.19
0517	+5.86	+-0.54	-3.01	+-0.89	+4.67	+-0.99
0518	+19.52	+-0.54	-24.81	+-0.93	-2.46	+-1.21
0519	+5.21	+-0.59	+4.27	+-0.52	+0.87	+-1.33
0520	+9.21	+-0.63	-6.07	+-0.71	+2.67	+-1.40
0521	+30.06	+-0.57	-38.20	+-1.19	-9.55	+-1.78
0522	+9.78	+-0.76	-6.29	+-1.17	+0.96	+-1.10
0523	+7.91	+-0.65	-5.08	+-1.03	+1.40	+-1.88
0524	+5.52	+-0.74	-2.21	+-1.04	+1.28	+-2.00
0525	+3.76	+-1.43	-0.73	+-2.48	+5.88	+-5.45
0526	+6.00	+-0.67	-1.22	+-0.76	+3.13	+-1.67
0528	+5.23	+-0.93	-2.93	+-1.35	+3.88	+-1.73
0529	+2.73	+-0.78	-1.75	+-1.36	+4.55	+-2.41
0531	+14.60	+-0.48	+12.21	+-0.71	+7.16	+-1.11
0532	+74.31	+-0.59	-35.06	+-0.61	-20.25	+-1.92
0781	+2.50	+-0.58	-4.26	+-0.65	+1.71	+-1.29
0782	+3.19	+-0.63	-6.01	+-0.72	+1.37	+-1.37
0783	+4.21	+-0.78	-4.92	+-1.14	+1.79	+-1.63
0786	+14.24	+-0.79	-22.15	+-1.45	-1.24	+-2.39
0787	+12.96	+-0.85	-17.87	+-0.91	-0.90	+-0.94
0788	+11.87	+-0.72	-16.26	+-0.90	-3.45	+-1.57
0789	+26.55	+-0.76	-30.07	+-0.95	-5.61	+-1.71
0790	+18.27	+-0.65	-12.15	+-0.95	-1.26	+-1.98
0791	+34.26	+-0.91	-42.19	+-1.37	-13.49	+-2.92
0792	+5.59	+-0.62	-2.83	+-0.95	+1.51	+-2.07
0793	+64.45	+-0.54	-44.65	+-0.94	-23.67	+-1.53