Global Positioning System Measurements on the Island of Hawai`i: 1997 through 2004

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Abstract

This report summarizes GPS data and observations collected between 1997 and 2004 on the island of Hawai`i with static surveying and continuously recording instruments.

On Kilauea, the long-term deformation field is dominated by steady southeastern velocities of more than 6 cm/year and uplift of about 2 cm/yr at stations on the south flank (with respect to a fixed Pacific Plate). Superimposed on this steady signal are transient displacements associated with magmatic intrusions, earthquakes, and aseismic slip events. The largest of these was the January 30, 1997 dike intrusion and eruption.

GPS instruments near Kilauea's summit also record numerous additional short-term fluctuations associated with variations in magma reservoir pressure and geometry. From mid-1997 through 2001, the dominant signal at the summit was deflationary, with maximum subsidence of ~5 cm/yr south of Kilauea caldera. However, inflation of the magma system was observed from late 2001 to May 2002, and from mid-2003 through 2004. The east rift zone eruption continued at the Pu`u `O`o vent during the entire period of this report.

Mauna Loa Volcano, which most recently erupted in 1984, showed low rates of contraction across the summit caldera and southeasterly motion of the southeast flank from 1997 until May 2002. Reinflation started abruptly in May 2002. Inflation continued through 2004, but at highly variable rates. Extension rates on a baseline across the summit caldera slowed in October 2002 and increased again starting in mid-2003. The most dramatic change during the inflation period, however, was a significant increase in extension rate on longer baselines, from the northwest to southeast flanks, in July 2004.

GPS measurements on Hualalai volcano show no significant motion relative to the Pacific Plate.

Introduction

Global Positioning System (GPS) measurements on the island of Hawai`i began in 1987, and have proven to be an effective tool in monitoring ground deformation associated with volcanic and volcano-tectonic activity in Hawai`i (e.g., Dvorak, 1994, Owen et al., 2000a,b, Segall et al.,

[1] U.S. Geological Survey, Hawaiian Volcano Observatory, Hawaii National Park, HI
[2] U.S. Geological Survey, Alaska Volcano Observatory, Anchorage, AK
[3] U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, WA
[4] NASA Jet Propulsion Laboratory, Pasadena, CA
[5] Department of Geophysics, Stanford University, Stanford, CA
[6] University of Hawai`i, Pacific GPS Facility, Manoa, HI

2001, Cervelli et al., 2002a,b). Sources of deformation on Hawai`i include the summit and rift zone magma systems of Kilauea and Mauna Loa, and slip along faults beneath their flanks (e.g., Delaney et al., 1998, Owen et al., 2000b, Cervelli and Miklius, 2003).

From 1997 through 2004, Kilauea Volcano erupted almost continuously from the Pu`u `O`o vent complex on the east rift zone, continuing the eruption that began in January 1983. There were, however, numerous pauses in eruptive activity (listed in Heliker and Mattox, 2003 and those lasting more than one day in table 1. Most of these lasted only one to two days, but several longer pauses occurred, notably in February 1997 following the Napau crater intrusion and eruption (Owen et al., 2000a) and in September 1999 following a smaller east rift zone dike intrusion (Cervelli et al., 2002b). There have been no discernible pauses since December 2000 (Heliker and Mattox, 2003).

Table 1*(A)*. Geologic events.

Event	Date	Deformation Reference
Napau Crater Intrusion and Eruption (Episode 54)	January 30, 1997	Owen et al., 2000a; Desmarais and Segall, in press
Lava erupts outside Pu`u `O`o crater	March 28, 1997	
M5.2 Kilauea South Flank Earthquake	June 30, 1997	Owen et al., 1997
Kilauea Summit Tilt Event/Eruptive surge	January 14, 1998	Larson et al., 2001
Kilauea South Flank Slip Event	September 19, 1998	
M5.6 Pahala Earthquake	April 16, 1999	Cervelli et al., 1999
Kilauea Upper East Rift Zone Intrusion	September 12, 1999	Cervelli et al., 2002b
Kilauea Upper East Rift Zone Intrusion	February 23, 2000	
M5.0 Kilauea South Flank Earthquake	April 1, 2000	
Kilauea South Flank Slip Event	November 10, 2000	Cervelli et al., 2002a
New vent opens at Pu`u `O`o, Mother's Day flow, start of Mauna Loa inflation	May 12, 2002	Miklius and Cervelli, 2003
Kilauea South Flank Slip Event	July 3, 2003	
M5.0 Kilauea South Flank Earthquake	Aug 26, 2003	

Numerous, short deflation-inflation-deflation (DID) events populate the time series of tilt measurements at the summit and at Pu`u `O`o (Cervelli and Miklius, 2003). Table 1*(B)* lists DID events since the start of concurrent operation of tiltmeters at the summit and at Pu`u `O`o in January 2000. These events usually occur on time scales of less than a day, thus they are better imaged in the GPS data with sub-daily solutions. However, several of the larger events can be discerned in daily-average solutions from summit stations, and occasionally coincide with changes in deformation rates at these stations.

There were five earthquakes of magnitude 5 or greater recorded on the island during this reporting period. The largest was a M5.6 earthquake on April 16, 1999 that originated about 9 km beneath the south flank of Mauna Loa. A M5.1 occurred on July 27 1998 in the Kohala region. The other three quakes were located between 9 and 10 km beneath the south flank of Kilauea on June 30, 1997, April 1, 2000, and Aug 26, 2003.

Table 1*(B)*. Deflation-inflation-deflation (DID) events since 2000 and pauses longer than one day.

DID's	Pauses
September 24 2000	Jan 31-Feb 24, 1997
April 7 2001	May 19, 1998
May 20 2001	July 16, 1998
December 9 2001	August 12, 1998
April 5 2002	November 7, 1998
January 21 2003	May 4, 1999
August 8 2003	June 14, 1999
March 4 2004	Sep 12-23, 1999
March 20 2004	October 3, 1999
May 15 2004	November 11, 1999
July 27 2004	August 23, 2000
	December 15, 2000

GPS at the Hawaiian Volcano Observatory

The Hawaiian Volcano Observatory (HVO) employs several methods of dual-frequency GPS surveying, including static, kinematic, and rapid-static. In collaboration with UNAVCO Inc., HVO also operates a network of single frequency, continuously recording GPS instruments. Several strategies and software packages are used to process the data, including kinematic and hourly average processing. However, we focus here on GPS data and observations collected from 1997 through 2004 on the island of Hawai`i with dual-frequency receivers, static surveying and continuously recording instruments, and daily-average solutions. Previous GPS data holdings are summarized in Miklius et al. (1994, 1997).

Continuous network

HVO, Stanford, and the University of Hawaii (UH) began building a network of continuously recording, dual frequency GPS receivers in 1995, with the installation of two sites spanning Kilauea's summit area (UWEV and MANE, figure 1). The number of stations grew steadily, and by the end of 2004, there were more than 30 continuously recording dual-frequency GPS stations monitoring Kilauea and Mauna Loa volcanoes. Table 2 provides the locations and installation dates for the continuous network.

At these sites, GPS antennas are mounted on threaded stainless steel rods set into bedrock (except station UWEV, which is set into the top of a cement vault) and surrounded by an 8-inch diameter PVC pipe filled with cement.

Data is collected every 30 seconds and transmitted hourly to the observatory via radio modem. We collected data from satellites orbiting higher than 5 degrees above the horizon until 1999, when we decreased the cut-off elevation angle to 0 degrees.

Data from the continuous network is archived both at HVO and at UNAVCO. Data and station equipment information are available from UNAVCO.

The NASA/International GPS Service (IGS) station near the summit of Mauna Kea supplements this network and provides a stable reference point. Although the IGS designation for this site is MKEA, we refer to it as MKPM to avoid confusion with an identically named campaign station. In addition to sites on the Island of Hawai`i, HVO includes data from GPS stations on other islands in the daily processing. These sites are operated by the UH and the IGS.

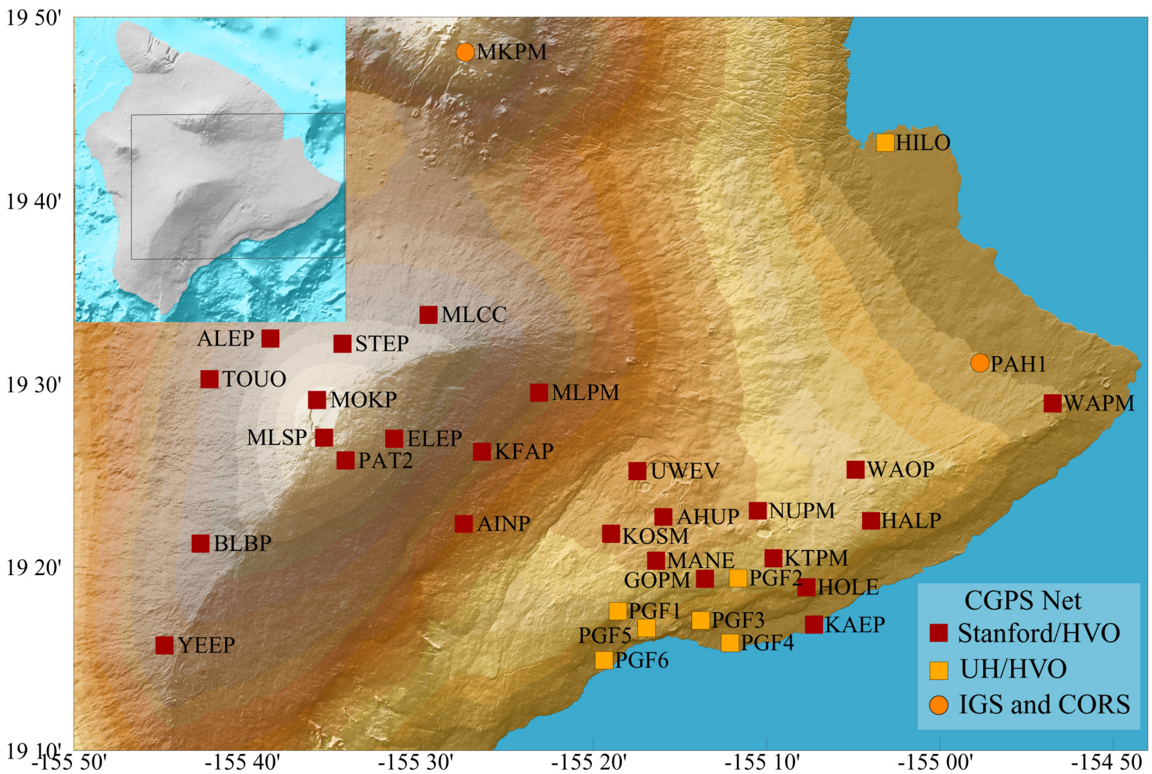

Figure 1. Continuous GPS network on the island of Hawai`i. Inset shows area of larger map.

Survey GPS

During static GPS surveying, the instrument is set up over a benchmark and records data every 30 seconds for anywhere from 8 to 24 hours. At remote, secure locations, such as those accessible only by helicopter, the instruments are usually left on-site to record data over several days. Survey GPS measurements were collected with Trimble 4000SSE, 4000SSI, and 5700 receivers. Data and log sheets are archived at HVO.

Benchmarks occupied with GPS between 1997 and 2004 are listed in table 3 and locations are shown in figure 2, categorized by networks of benchmarks that are usually occupied during a single campaign. Note that some sites are common to more than one network. Table 4 lists survey dates for each benchmark, in UTC. Sessions often cross a UTC date boundary; the date listed is the day in which the bulk of the data is collected. The Kilauea and Mauna Loa networks are occupied at least once yearly. The Hualalai and West Mauna Loa networks are occupied about once every two years. An additional network of densely spaced benchmarks formerly occupied with EDM spans Kilauea's Koa`e fault system. This network, last measured with GPS in May 2003, is not listed here; information on this net is available from the authors.

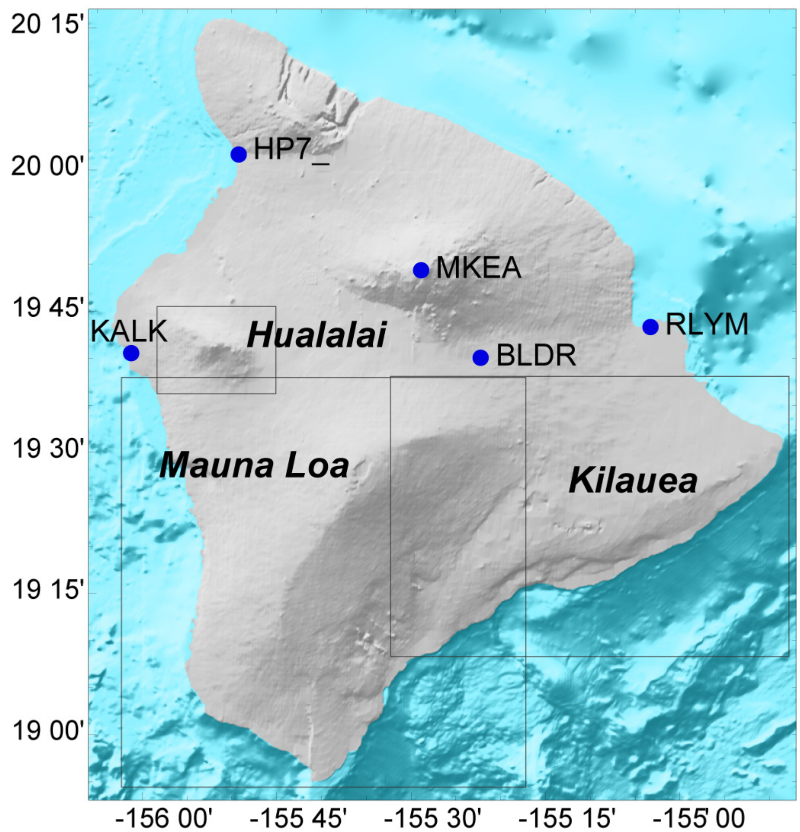

Figure 2 (*A*). Map of Hawai`i Island showing the location of "miscellaneous" GPS survey benchmarks (blue dots), which are often occupied with several networks. Boxes indicate the areas of the survey GPS benchmark location maps of figures 2(*B*) - (*D*).

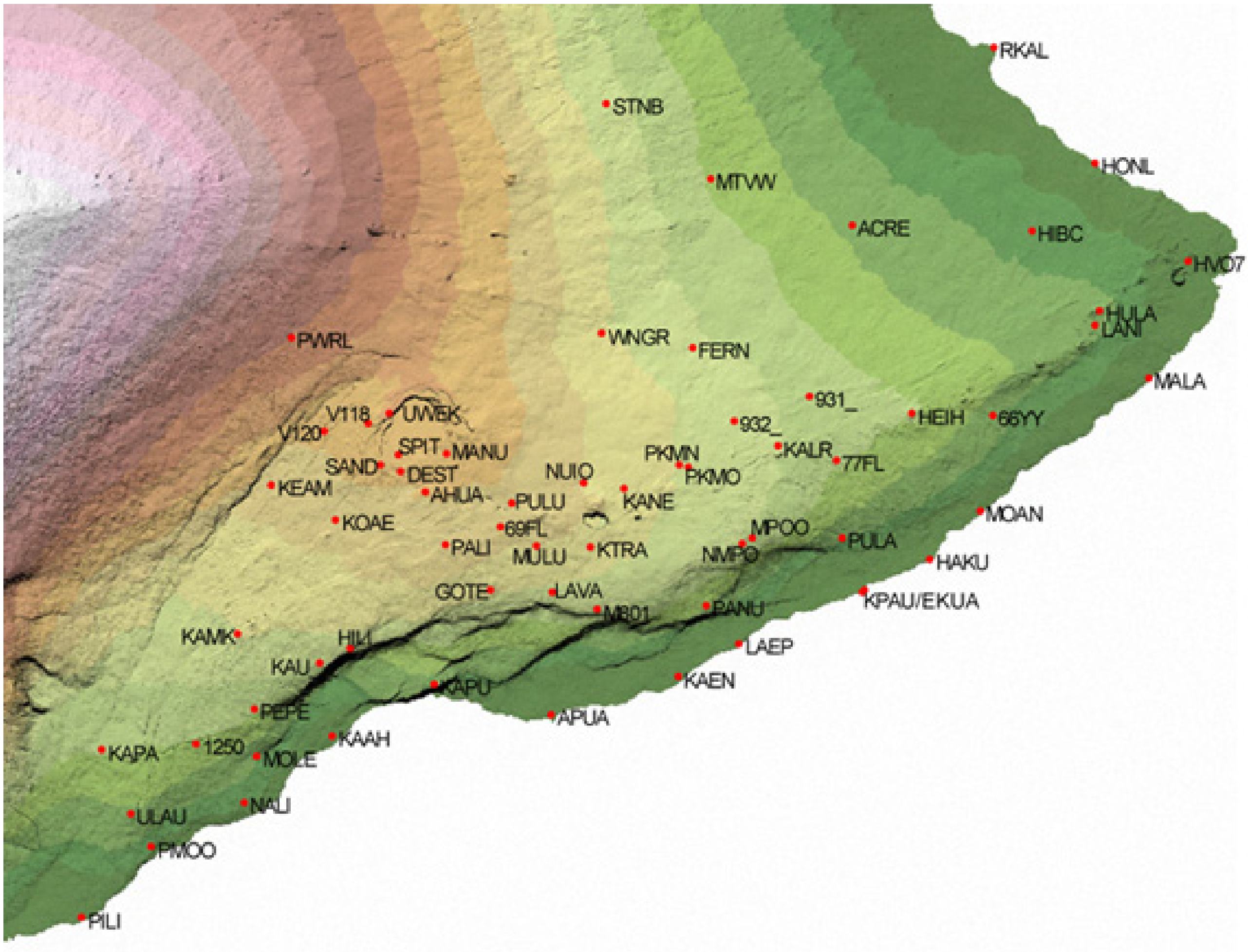

Figure 2 (*B*). The Kilauea survey GPS network.

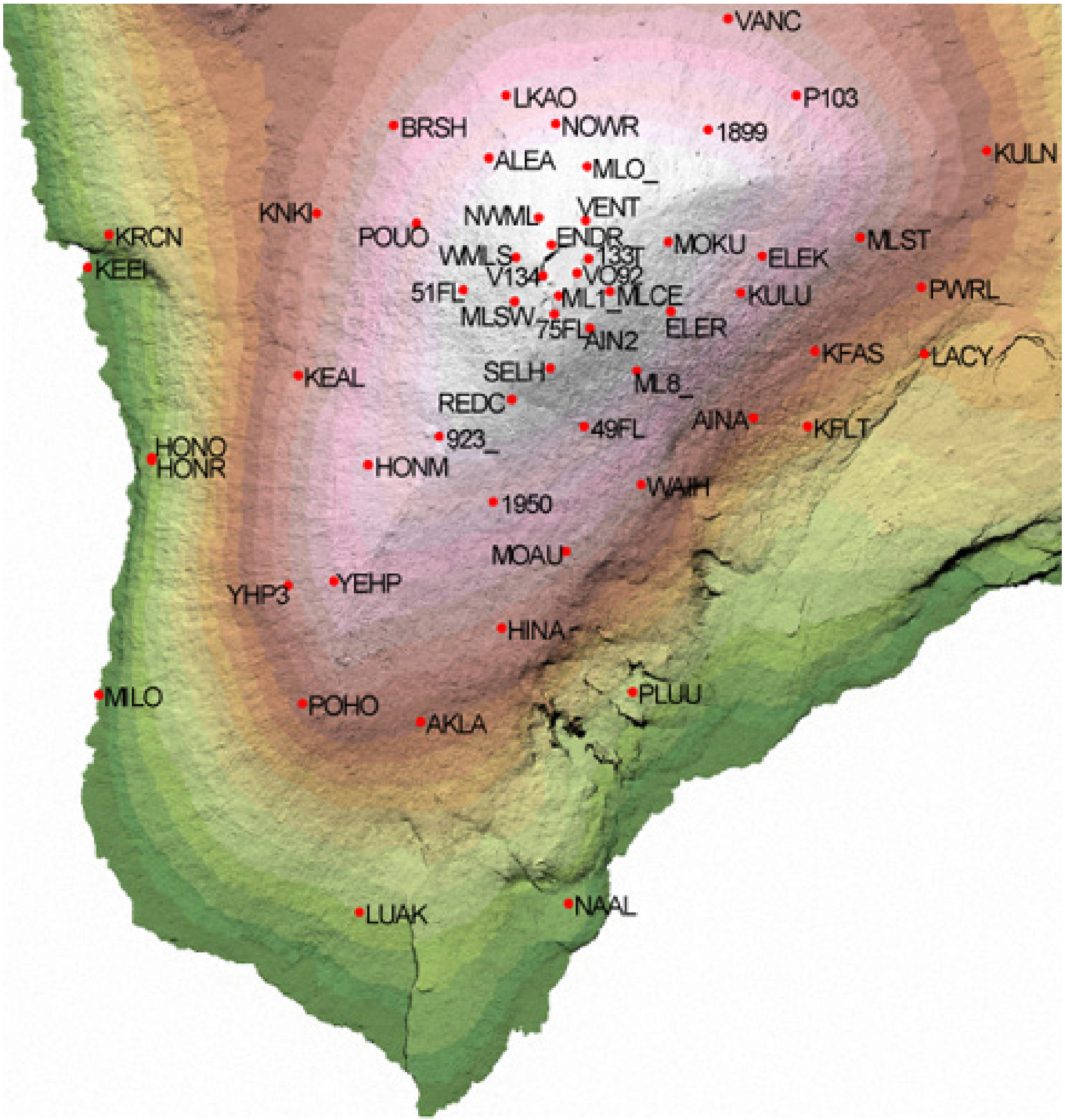

Figure 2 (*C*). The Mauna Loa survey GPS network.

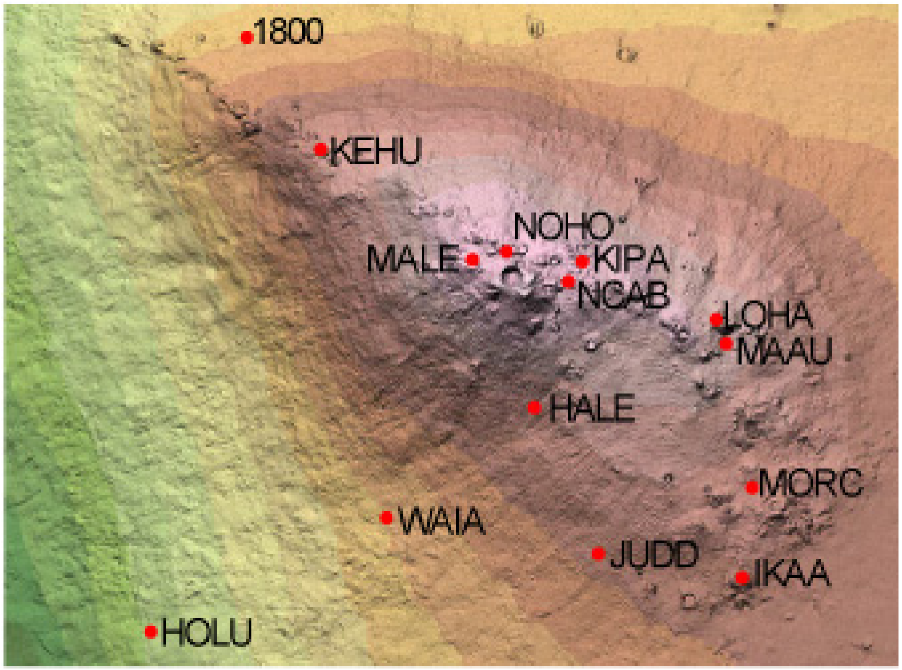

Figure 2 (*D*). The Hualalai survey GPS network.

Data Processing

Data collected by the continuous network are telemetered to HVO in hourly files. Processing the data in near-real-time has been discussed by Larson et al. (2001). The emphasis here, however, will be on daily-average solutions. We process all dual-frequency GPS data using the GIPSY/OASIS II software (Lichten and Border, 1987) with non-fiducial orbits and a precise point positioning strategy (Zumberge et al., 1997). Phase ambiguities are fixed to their integer values when possible. The non-fiducial solutions are then transformed into a global ITRF reference frame with a 7-parameter Helmert transformation using daily parameters provided by the Jet Propulsion Laboratory (JPL). The processing also employs azimuthal tropospheric gradients, which permit more robust estimation of the tropospheric path delays in this region of highly variable, wet tropospheric conditions (Bar-Sever et al., 1998). The estimation of tropospheric gradients requires information from low-angle paths; for this reason an elevation mask of 5 degrees is used. The processing method has evolved over time. However, when a major change of method is implemented, it has been our policy to re-process the older data to create a consistent time series. All of the time series presented here reflect the processing strategy given above.

Results

The most significant signal in the Kilauea time series is the large and generally steady seaward motion of stations on the south flank with respect to the Pacific Plate. Superimposed on this steady-state deformation are short-lived events that introduce offsets into the time series (table 1, figures 3*(A)*, 3*(B)*, 5). The largest of these was the January 1997 intrusion and eruption, which caused large perturbations at many sites that lasted for months (Owen et al., 2000a, Desmarais and Segall, in press). Velocities returned to previous rates by mid-1997, and thus the average velocities from 1997 to 2002 shown in figure 4*(A)* and listed in table 5*(A)* for Kilauea stations are calculated from July 1997. In late 2001, the continuous GPS network began to record the first sustained inflation of Kilauea since the stations were installed. Inflation ceased with the opening of a new, high-volume vent on Pu`u `O`o on May 12, 2002 (Miklius and Cervelli, 2003). Inflation resumed in mid-2003 and continued through 2004, with high extension rates across the summit (figure 3*(B)*) and uplift of summit station UWEV. Baselines that cross the calderas of both Kilauea and Mauna Loa (figure 3*(B)*, *(C)*) have generally proven to be good proxies for inflation status. These also show numerous short perturbations and changes in extension rates on scales of days to weeks. On Kilauea, most of these are associated with short-lived volcanic events such as pauses in the eruption, or deflation-inflation-deflation cycles that usually end with a surge of lava production at Pu`u `O`o (Cervelli and Miklius, 2003).

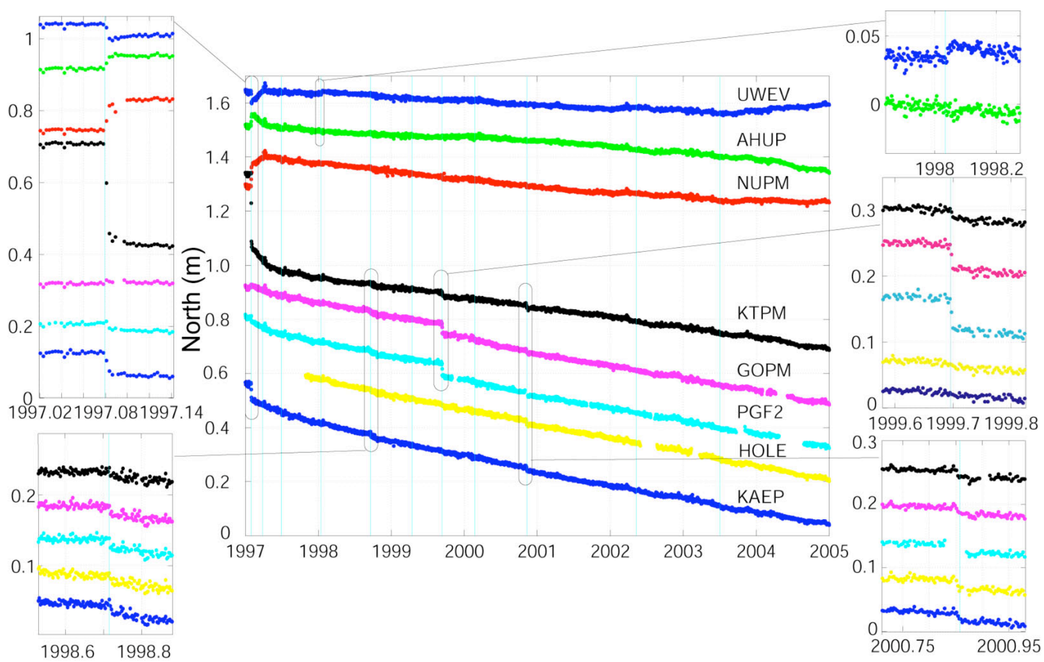

Figure 3 *(A)*. The north component of selected continuous GPS stations relative to MKPM. Vertical lines mark geologic events listed in table 1(*A*). See figure 1 for station locations.

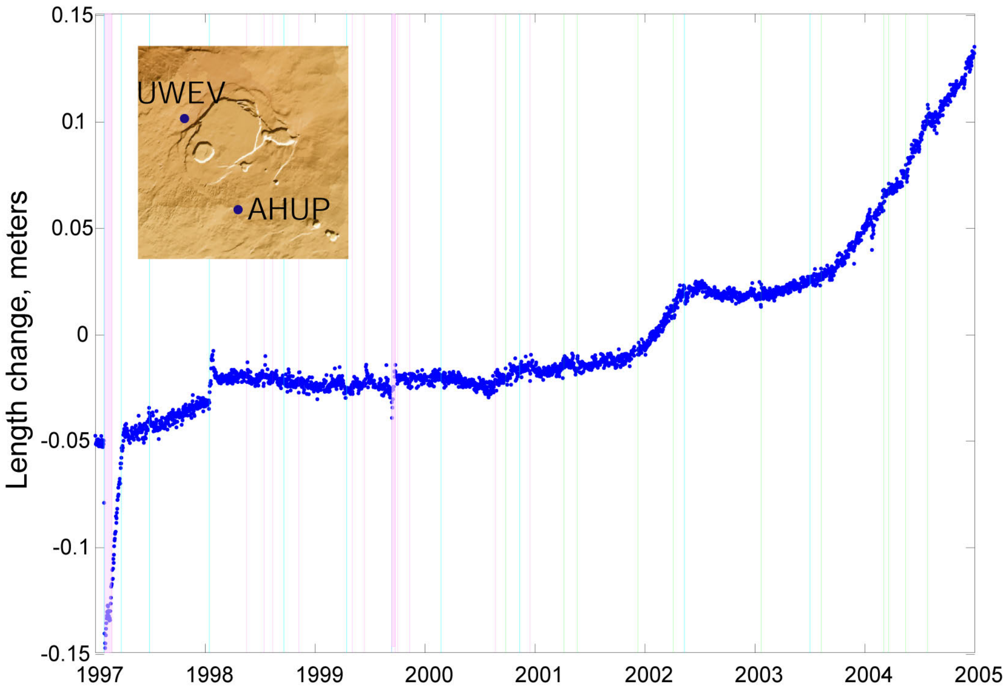

Figure 3 (*B*). Line length change between Kilauea summit stations. Light blue vertical lines mark geologic events (table 1(*A*)), green lines mark DID events (table 1(*B*)) and pink lines mark pauses (table 1(*B*)).

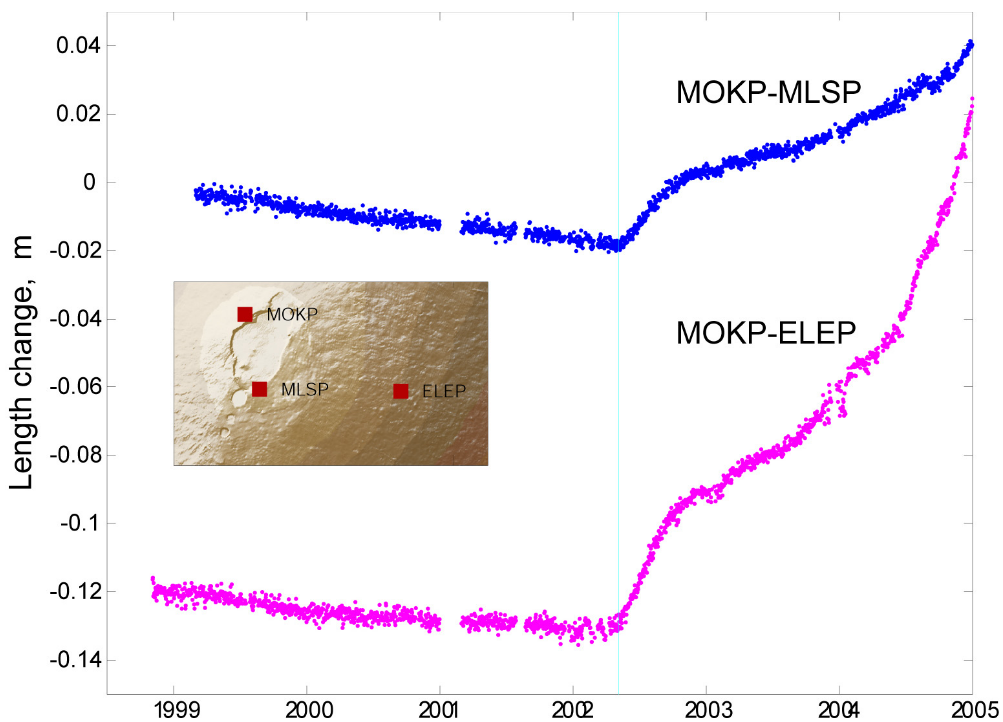

Figure 3 (*C*). Line length change between Mauna Loa summit stations, in blue, and flank stations, in pink. The vertical line marks the start of reinflation on May 12, 2002.

Mauna Loa's summit, which had been extending and uplifting since its most recent eruption in 1984 until mid-1993 (Miklius et al., 1995), showed very low rates of deformation between 1997 and 2002 (figures 3*(C)*, 4*(A)*). The summit area contracted and subsided, and most stations moved southeastward, with maximum horiontal velocities observed on the upper southeast flank. Reinflation started abruptly in May 2002 (Miklius and Cervelli, 2003). The initially high inflation rates continued until October 2002, then slowed until mid-2003. Inflation rates accelerated dramatically in mid-2004, best illustrated by the acceleration of extension of longer baselines from the northwest to southeast flanks (fig. 3*(C)*). This acceleration coincided with the start of a swarm of deep, long-period earthquakes. The high rate of inflation continued through 2004, though the deep seismicity abated at the end of 2003.

GPS measurements on Hualalai volcano show no significant motion relative to the Pacific Plate (fig. 4*(C)*).

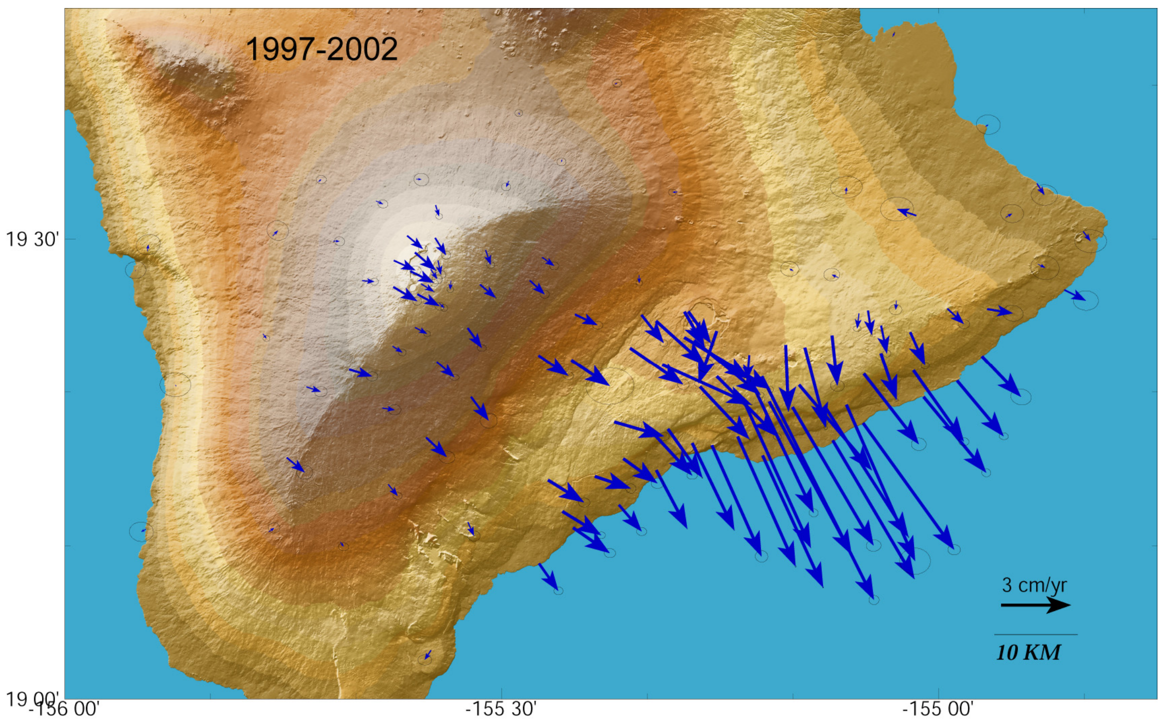

Figure 4 (*A*). Average horizontal displacement rates from 1997 through 2002. The velocity of the permanent station on the summit on Mauna Kea (MKPM) has been removed (this velocity is listed in table 5). See table 5*(A)* for specific dates. 2-sigma error ellipses are based on the fit to a linear velocity.

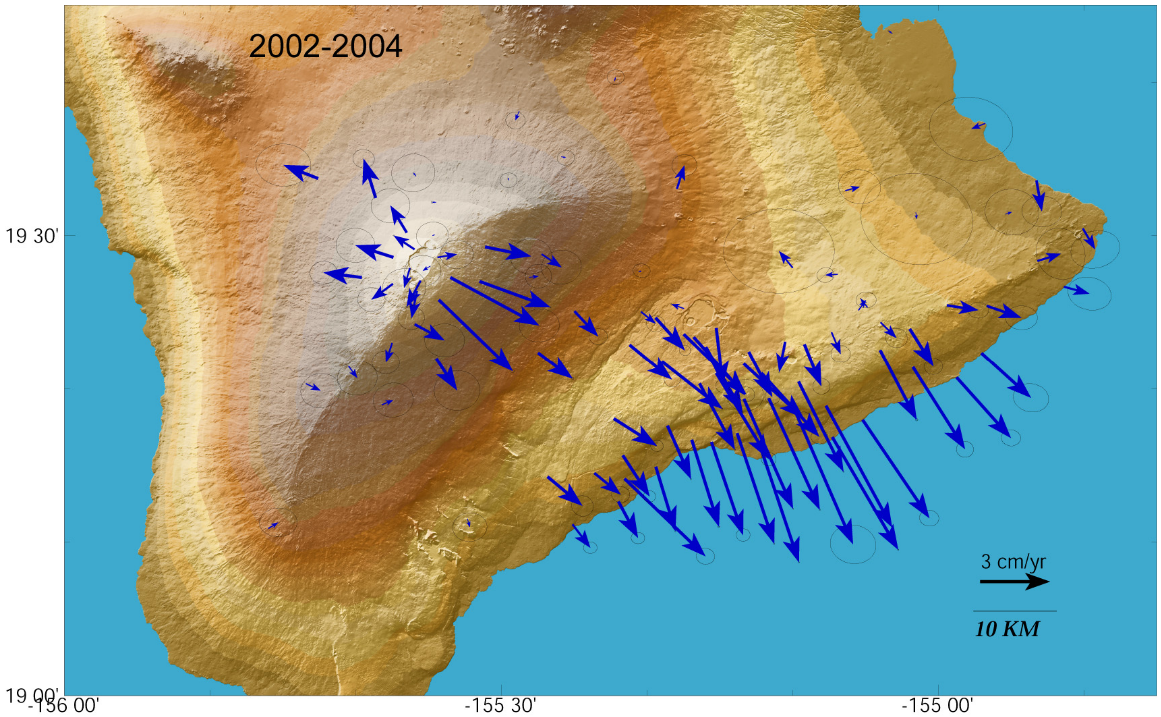

Figure 4 (*B*). Average horizontal displacement rates from 2002 through 2004. The velocity of the permanent station on the summit on Mauna Kea (MKPM) has been removed (this velocity is listed in table 5). See table 5*(B)* for specific dates. 2-sigma error ellipses are based on the fit to a linear velocity.

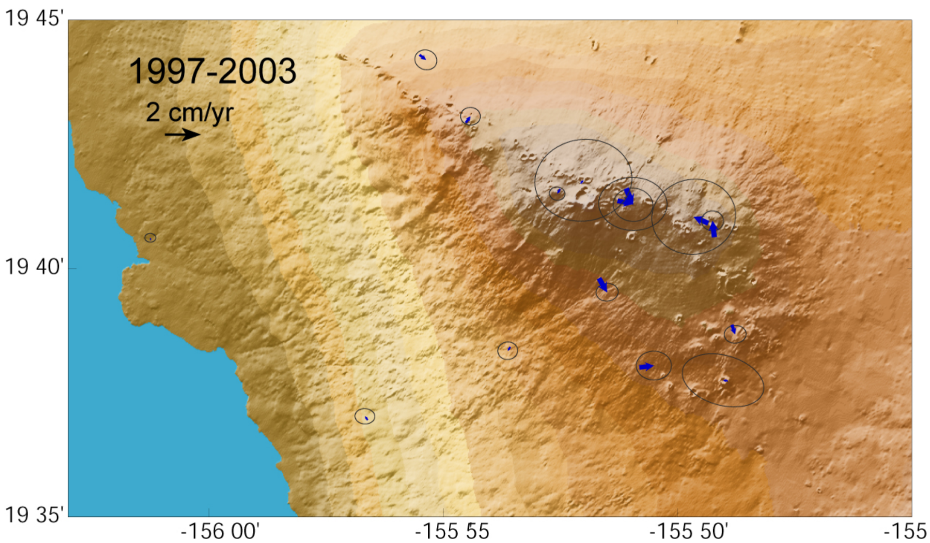

Figure 4 (*C*). Average horizontal displacement rates on Hualalai Volcano from 1997 to 2003. The velocity of the permanent station on the summit on Mauna Kea (MKPM) has been removed (this velocity is listed in table 5). 2-sigma error ellipses are based on the fit to a linear velocity.

Time series for each of the continuous sites on Mauna Loa and Kilauea volcanoes are given in figure 5. These time series are plotted relative to the permanent station on the summit on Mauna Kea (MKPM) in order to minimize reference frame error and apparent seasonal and interannual variations that are common to all sites (these can still be seen on the detrended MKPM time series in figure 5*(K)*). Note that this does introduce a small, spurious vertical signal in all the time series at the 1999-2000 year boundary. The formal errors are not depicted in these time series because their inclusion causes excessive clutter; inspection of the day-to-day scatter gives a qualitative impression of the errors.

The continuous GPS network has proved to be a highly effective tool for monitoring both long-term deformation and the variations in deformation rates that are crucial to understanding the magma system and structure of Hawaii's active volcanoes.

Table 2. Continuously recording GPS stations: codes, locations in WGS84, and notes

code	longitude	latitude	installation date	
AHUP	-155.2661	19.3791	7/20/1996	
AINP	-155.4580	19.3727	10/8/2002	
ALEP	-155.6441	19.5412	7/15/2004	
BLBP	-155.7114	19.3546	6/12/2004	
ELEP	-155.5249	19.4503	10/22/1998	
GOPM	-155.2224	19.3223	8/15/1996	
HALP	-155.0665	19.3756	12/28/1999	Overrun by lava flows in May 2002, replaced by HALR
HALR	-155.0665	19.3756	2/1/2003	
HILO	-155.0527	19.7192	6/15/1997	
HOLE	-155.1285	19.3149	10/30/1997	
KAEP	-155.1214	19.2809	7/20/1996	
KFAP	-155.4406	19.4384	7/18/2004	
KOSM	-155.3165	19.3633	5/15/1997	
KTPM	-155.1601	19.3413	11/1/1996	
MANE	-155.2733	19.3391	7/29/1995	
MKPM	-155.4563	19.8014	9/26/1996	NASA IGS station
MLCC	-155.4920	19.5627	7/2/2004	
MLPM	-155.3859	19.4920	1/28/1997	
MLSP	-155.5924	19.4512	3/2/1999	
MOKP	-155.5994	19.4853	11/4/1998	
NUPM	-155.1753	19.3847	10/10/1996	
PAT2	-155.5717	19.4304	11/1/2002	
PGF1	-155.3101	19.2933	9/6/1996	
PGF2	-155.1941	19.3232	9/6/1996	
PGF3	-155.2302	19.2850	11/3/1996	
PGF4	-155.2018	19.2646	9/7/1996	
PGF5	-155.2823	19.2779	9/1/1996	
PGF6	-155.3233	19.2486	9/6/1996	
STEP	-155.5748	19.5366	10/11/2002	
TOUO	-155.7028	19.5043	7/10/2004	
UWEV	-155.2911	19.4209	5/27/1995	
WAOP	-155.0811	19.4221	12/18/1999	
WAPM	-154.8916	19.4823	5/12/2004	
YEEP	-155.7462	19.2622	8/18/2004	

Table 3. Survey GPS benchmarks: codes, locations in WGS84, and notes

Code	Latitude	Longitude	Notes
1250	-155.3937	19.2419	
133T	-155.5731	19.4765	
1800	-155.9250	19.7383	
1899	-155.4920	19.5627	reset to continuous station MLCC 2004
1950	-155.6366	19.3161	
49FL	-155.5745	19.3663	
51FL	-155.6597	19.4545	
66YY	-154.9446	19.4239	
69FL	-155.2227	19.3608	
75FL	-155.5968	19.4398	
77FL	-155.0328	19.3987	
923_	-155.6748	19.3579	
931_	-155.0487	19.4330	reset to continuous station WAOP 1999
932_	-155.0913	19.4191	
ACRE	-155.0257	19.5252	
AHUA	-155.2661	19.3791	reset to continuous station AHUP 1996
AIN2	-155.5717	19.4304	reset to continuous station PAT2 2004
AINA	-155.4580	19.3733	reset to continuous station AINP 2002
AKLA	-155.6848	19.1705	
ALEA	-155.6438	19.5411	reset to continuous station ALEP 2004
APUA	-155.1927	19.2599	reset to continuous station PGF4 1996
BLDR	-155.3705	19.6680	
BRSH	-155.7096	19.5620	
DEST	-155.2800	19.3897	
EKUA	-155.0160	19.3294	reset from KPAU
ELEK	-155.4540	19.4800	
ELER	-155.5163	19.4428	reset to continuous station ELEP 1998
ENDR	-155.5989	19.4856	reset from HVO93, reset to continuous station MOKP 1998
FERN	-155.1153	19.4581	
GOTE	-155.2281	19.3265	reset to continuous station GOPM 1996
HAIL	-156.3433	20.8512	
HAKU	-154.9791	19.3459	
HALE	-155.8612	19.6634	
HANA	-156.0145	20.7959	
HEIH	-154.9902	19.4242	
HIBC	-154.9233	19.5235	
HILI	-155.3073	19.2945	reset to continuous station PGF1 1996
HINA	-155.6299	19.2332	
HKHI	-156.1794	20.7350	
HOLU	-155.9435	19.6159	
HONL	-154.8877	19.5599	BM may be unstable
HONM	-155.7236	19.3390	
HONO	-155.8730	19.3416	reset to HONR 1999
HONR	-155.8727	19.3397	reset from HONO
HP7_	-155.8207	20.0268	
HULA	-154.8844	19.4806	
HVO7	-154.8346	19.5078	
IKAA	-155.8155	19.6290	
JUDD	-155.8468	19.6335	
KAAH	-155.3168	19.2471	reset to continuous station PGF6 1996
KAEN	-155.1215	19.2812	reset to continuous station KAEP 1996
KALK	-156.0206	19.6762	
KALR	-155.0661	19.4059	

Table 3 continued. Survey GPS benchmarks			
Code	Latitude	Longitude	Notes
KAMK	-155.3713	19.3010	
KANE	-155.1534	19.3818	
KAPA	-155.4472	19.2378	
KAPU	-155.2596	19.2757	
KAU_	-155.3244	19.2862	
KEAL	-155.7732	19.3969	
KEAM	-155.3532	19.3814	
KEEI	-155.9193	19.4654	
KEHU	-155.9085	19.7156	
KFAS	-155.4163	19.4180	reset to continuous station KFAP 2004
KFLT	-155.4206	19.3682	
KHUA	-156.2965	20.6787	
KIPA	-155.8515	19.6935	
KNAE	-156.1439	20.8623	
KNKI	-155.7623	19.5031	
KOAE	-155.3165	19.3633	reset to continuous station KOSM 1997
KOLE	-156.2562	20.7073	
KOLI	-155.5411	19.6344	
KPAU	-155.0175	19.3281	overrun by lava 2001
KRCN	-155.9056	19.4868	
KTRA	-155.1717	19.3505	reset to continuous site KTPM 1997
KULN	-155.2992	19.5508	
KULU	-155.4680	19.4550	
LACY	-155.3403	19.4174	
LAEP	-155.0868	19.2996	
LANI	-154.8868	19.4725	
LAVA	-155.1929	19.3261	reset to continuous station PGF2 1996
LEIE	-156.0473	20.6531	
LKAO	-155.6322	19.5831	
LOHA	-155.8224	19.6819	
LOOK	-156.2340	20.7368	
LUAK	-155.7249	19.0450	
LUAL	-156.3060	20.6096	
M801	-155.1674	19.3170	
MAAU	-155.8202	19.6772	
MALA	-154.8563	19.4447	
MALE	-155.8752	19.6933	
MANU	-155.2541	19.3998	
MILO	-155.9071	19.1845	
MKEA	-155.4810	19.8228	
ML1_	-155.5935	19.4518	reset to continuous station MLSP 1998
ML8_	-155.5393	19.4033	
MLCE	-155.5582	19.4547	
MLO_	-155.5757	19.5365	reset to continuous station STEP 2002
MLST	-155.3857	19.4924	reset to continuous station MLPM 1997
MLSW	-155.6243	19.4479	
MOAN	-154.9508	19.3724	
MOAU	-155.5866	19.2841	
MOKU	-155.5187	19.4878	
MOLE	-155.3593	19.2358	
MORC	-155.8139	19.6478	
MPOO	-155.0799	19.3564	overrun by lava 1997
MTVW	-155.1065	19.5490	

Table 3 continued. Survey GPS benchmarks			
Code	**Latitude**	**Longitude**	**Notes**
MULU	-155.2025	19.3504	
NAAL	-155.5810	19.0530	
NALI	-155.3662	19.2109	
NCAB	-155.8546	19.6894	
NIAN	-156.2449	20.7724	
NMPO	-155.0859	19.3534	replacement for MPOO, overrun by lava 2002
NOHO	-155.8677	19.6952	
NOWR	-155.5979	19.5646	
NUIO	-155.1762	19.3851	
NWML	-155.6082	19.5033	
P103	-155.4315	19.5857	
PALI	-155.2542	19.3505	
PANU	-155.1059	19.3196	reset to continuous site HOLE 1997
PEPE	-155.3612	19.2611	
PILI	-155.4574	19.1475	
PKMN	-155.1222	19.3952	replacement for PKMO
PKMO	-155.1172	19.3938	overrun by lava 1998
PLUU	-155.5390	19.1922	
PMOO	-155.4185	19.1862	
POHO	-155.7667	19.1817	
POLI	-156.3015	20.7124	
POUO	-155.6929	19.4976	
PULA	-155.0293	19.3570	
PULU	-155.2170	19.3736	
PUUI	-156.3873	20.6827	
PWRL	-155.3430	19.4608	
REDC	-155.6251	19.3836	
RKAL	-154.9464	19.6218	
RLYM	-155.0548	19.7228	reset to continuous station HILO 1997
SAND	-155.2914	19.3929	
SELH	-155.5991	19.4038	
SPIT	-155.2812	19.3985	
STNB	-155.1658	19.5889	overgrown with large trees
ULAU	-155.4307	19.2038	
UWEK	-155.2868	19.4211	displaced ~autumn 2001, reset as UWER
UWER	-155.2868	19.4211	reset of UWEK, possibly not well tied to ground
V118	-155.2988	19.4152	
V120	-155.3236	19.4109	
V134	-155.6046	19.4648	
VANC	-155.4796	19.6349	
VENT	-155.5763	19.5010	
VO92	-155.5815	19.4669	
WAIA	-155.8927	19.6403	
WAIH	-155.5352	19.3281	
WMLS	-155.6236	19.4764	
WNGR	-155.1667	19.4651	
YEHP	-155.7461	19.2621	reset to continuous station YEEP 2004
YHP3	-155.7776	19.2588	

Table 4a. Kilauea GPS survey benchmarks and occupation dates

Code	1997			1998		1999	2000	2001	2002	2003	2004
'1250'		6/22-23/1997			6/27-29/1998	6/26-28/1999	6/24-26/2000	6/30-7/1/2001	7/8/2002	9/13-15/2003	8/13-15/2004
'66YY'		6/15/1997, 7/16/1997			6/23/1998	6/22,29/1999	6/21-22/2000	6/27/2001	7/16/2002	9/17/2003, 10/17/2003	9/22-23/2004
'69FL'	1/16-17/1997, 2/4/1997	6/18-19/1997	9/9/1997	1/9/1998, 4/16/1998	6/26/1998	6/26-27/1999, 9/14/1999	3/1-2/2000, 6/24-25/2000	7/7-8//2001	7/10-11/2002	8/21/2003	4/28-30/2004, 9/21-23/2004
'77FL'	2/5/1997	6/17-18/1997, 7/3-7/1997			6/23-24/1998	6/22-23/1999	6/20-21/2000	6/26-27/2001	7/4-5/2002	9/9-102003	8/11-12/2004
'931_'	2/6/1997	6/17-18/1997			6/23-24/1998	6/22/1999	6/20-21/2000	6/26-27/2001			
'932_'	2/6/1997, 5/8-13/1997	6/17-18/1997, 7/3-7/1997			6/23-24/1998	6/22-23/1999	6/20-21/2000	6/26-27/2001	7/4-5/2002	9/12/2003	8/11-12/2004
'ACRE'		6/17-18/1997			6/29/1998	6/22,30/1999	6/22,26/2000	6/26/2001	7/17/2002	9/19/2003	12/8/2004
'AHUA'			9/18/1997								
'APUA'		6/19-20/1997									
'DEST'	1/21/1997, 2/4/1997	6/21-23/1997	9/10/1997	1/10-12, 1/16, 4/17-18/1998	6/27-28/1998	6/26-28/1999	6/24-26/2000	6/30-7/2/2001	7/10-11/2002	8/21/2003	4/23/2004
'EKUA'								3/8/2001	7/4-5/2002	9/9-10/2003	8/11-12/2004
'FERN'	2/20/1997	6/18/1997, 6/24/1997	8/14/1997		6/23-24/1998	6/22-23/1999	6/21-22/2000	7/18/2001	7/25-28/2002	10/31-11/1/2003	9/15-16/2004
'GOTE'	1/18-23/1997										
'HAKU'		6/17-18/1997, 7/1-3/1997			6/23-24/1998	6/22-23/1999	6/20-21/2000	6/26-27/2001	7/4-5/2002	9/9-10/2003	8/11-12/2004
'HEIH'		6/17-18/1997			6/23-24/1998	6/22-23/1999	6/20-21/2000	6/26-27/2001	7/4-5/2002	9/9-10/2003	8/11-12/2004
'HIBC'		6/17/1997			6/22/1998, 8/7/1998	6/23, 28/1999	6/20,22/2000	6/27/2001, 7/3/2001	7/16/2002	9/12/2003	7/26,29/2004
'HILI'	1/22/1997	6/21-22/1997									
'HONL'		6/17/1997, 6/25/1997			6/30/1998, 8/7/1998	6/23, 29/1999	6/28-29/2000		7/16/2002	10/15/2003	8/23,27/2004, 9/15/2004
'HULA'									7/17-18/2002	9/20/2003	9/22-23/2004
'HVO7'		6/17/1997			6/23/1998, 8/9/1998	6/21, 30/1999	6/28-29/2000	7/5/2001	7/16/2002	9/16/2003, 10/15/2003	6/28/2004, 8/26/2004

Table 4a continued. Kilauea GPS surveys

Code	1997			1998		1999	2000	2001	2002	2003	2004
'KAAH'		6/21-23/1997									
'KAEN'	1/16-17/1997		9/16/1997					8/9-12/2001			
'KALR'	2/5/1997	6/17-18/1997, 7/4-7/1997			6/23-24/1998	6/22-23/1999	6/20-21/2000	6/26-27/2001	7/4-5/2002	9/12/2003	8/11-12/2004
'KAMK'		6/21-23/1997			6/27-29/1998	6/24-25/1999	6/24-26/2000	6/30-7/2//2001	7/6-8/2002	9/13-14/2003	8/13-15/2004
'KANE'	2/7, 3/22-29, 4/2-24, 5/7-30/1997	6/19-20/1997	8/2-11/21/1997		6/25-26/1998	6/24-25/1999, 10/14-31/1999	6/22-23/2000	6/28/2001	7/4-5/2002	9/12/2003	8/11-12/2004
'KAPA'		6/21-22/1997			6/27-28/1998	5/1-3/1999, 6/26-28/1999	6/19-20/2000	6/5-6/2001	7/10-11/2002		6/16-17/2004
'KAPU'		6/19-20/1997			6/25-26/1998	6/24-25/1999	6/22-23/2000	6/28-29/2001	7/6-8/2002	9/10/2003	8/13-14/2004
'KAU_'		6/19-20/1997			6/25-26/1998	6/24-25/1999	6/22-23/2000	6/28-29/2001	7/6-8/2002		
'KEAM'	2/21/1997	6/21-22/1997			6/27-28/1998	6/26-28/1999	6/27-29/2000	6/5-6/2001	7/10-11/2002	4/3/2003, 8/23-26/2003	6/15-16/2004
'KOAE'	1/19-20/1997, 3/5-4/23/1997	6/27-30/1997									
'KPAU'	2/5/1997	6/17-18/1997, 7/1-3/1997			6/23-24/1998	6/22-23/1999		3/8/2001, 6/26-27/2001			
KTRA	2/7/1997										
'LAEP'	2/19/1997	6/20/1997, 7/1/1997	10/1/1997, 11/11/1997		6/26/1998	6/25, 30/1999	6/24-26/2000	6/27/2001	7/12/2002		9/21-23/2004
'LANI'		6/17/1997, 6/23/1997			6/30/1998	6/28/1999	6/28-29/2000	6/28/2001	7/16/2002	9/17/2003	8/20/2004
'LAVA'	1/16/1997	6/20/1997	9/16/1997								
'M801'	2/19/1997	6/19/1997, 7/1/1997	10/1/1997		6/24-30/1998	6/25/1999	6/23,26/2000	8/5-8,12/2001	7/12/2002	7/5,8-10/2003	
'MALA'		6/15/1997, 6/19/1997			6/22,25/1998	6/21,24/1999	6/19,28/2000	6/28/2001	7/16/2002	9/10/2003, 10/7/2003	7/15,28/2004

Table 4a continued. Kilauea GPS surveys

Code	1997			1998		1999	2000	2001	2002	2003	2004
'MANU'	1/17/1997, 2/4/1997	6/24-25/1997	9/10/1997	1/8,1/21, 4/16/1998	6/28-29/1998	6/25/1999	3/1-2/2000, 6/24-25/2000	7/3-5/2001	3/19-20/2002, 7/10-11/2002	8/21/2003	4/28-30/2004
'MOAN'		6/15,25/1997, 7/16/1997			6/22/1998	6/28-29/1999	6/19/2000	6/25/2001, 7/3/2001	7/16/2002	9/17/2003	7/22/2004, 8/24-25/2004
'MOLE'								6/30-7/2/2001	7/6-8/2002		8/13-14/2004
'MPOO'	2/6, 3/22, 5/8-9, 5/11-13/1997	6/19-20/1997, 7/1-3/1997									
'MTVW'		6/19/1997, 6/24/1997			6/22, 25/1998	6/23, 29/1999	6/27-28/2000	6/25/2001	7/17/2002	10/25/2003	7/20,27/2004
'MULU'	2/7, 3/22/1997	6/19-20/1997				6/24-25/1999, 9/14/1999	3/4-6/2000, 6/22-23/2000	6/28-29/2001	7/4-5/2002	9/12/2003	8/13-15/2004
'NALI'		6/21-23/1997			6/27-29/1998	6/26-28/1999	6/24-26/2000	6/30-7/1/2001	7/6-8/2002	9/13-14/2003	8/13-15/2004
'NMPO'					7/22-23/1998	6/24-25/1999	6/20-21/2000	6/28-29/2001			
'NUIO'	2/7/1997										
'PALI'	1/22-23/1997, 2/8-10/1997	6/21-22/1997	9/9/1997	1/13/1998, 4/18/1998	6/27-28/1998	6/26-28/1999	6/23-26/2000	6/28-29/2001	7/10-11/2002	5/17-19/2003, 8/21/2003	9/21-23/2004
'PANU'	2/1-4/1997, 3/22/1997	6/19-20/1997, 7/4-7/1997			6/25-26/1998						
'PEPE'		6/21-23/1997			6/25-26/1998	6/24-25/1999	6/22-23/2000	6/28-29/2001	7/6-8/2002	9/12-13/2003	8/13-15/2004
'PILI'		6/19-20/1997			6/27-28/1998	5/4/1999	6/24-26/2000	6/30-7/1/2001		9/13-15/2003	6/24-25/2004
'PKMN'					6/26/1998	6/24-25/1999	6/22-23/2000	6/28-29/2001	7/4/2002	9/12/2003	8/11-12/2004
'PKMO'	1/30, 2/6,5/7-9, 5/11-30/1997										
'PMOO'		6/21-23/1997			6/27-29/1998	6/26-28/1999	6/24-26/2000	6/30-7/1/2001	7/6-8/2002	9/13-14/2003	8/13-15/2004

Table 4a continued. Kilauea GPS surveys

Code	1997			1998		1999	2000	2001	2002	2003	2004
'PULA'	2/5/1997	6/17-18/1997, 7/1-3/1997			6/23-24/1998	6/22-23/1999	6/20-21/2000	6/26-27/2001	7/4-5/2002	9/9-10/2003	8/11-12/2004
'PULU'	1/22-23, 1/31-2/3,2/28-3/21/1997	6/24-25/1997, 7/1/1997	9/6-8/1997	1/8,1/21, 4/16/1998	6/28-29/1998	6/26-28/1999, 9/21-22/1999	4/30-5/1/2000, 6/22-23/2000	7/3-5/2001	3/20-21/2002, 7/10-11/2002	8/21/2003	4/28-30/2004, 9/21-23/2004
'PWRL'	1/18-21, 2/27, 3/1-5/1997	6/11-12/1997	9/20-22/1997	1/13/1998	6/6-8/1998	6/8-10/1999	5/25-26/2000	5/31/2001, 6/2-4/2001	7/25/2002	3/11-12/2003	9/28-29/2004
'RKAL'		6/15/1997, 6/24/1997			6/24,29/1998	6/22/1999	6/28-30/2000	6/28/2001	7/16/2002	9/19/2003	
'SAND'	1/19-20, 2/1-3, 3/6-21/1997	6/21-22/1997	9/6-10/1997	1/10-12/1998, 1/16-19/1998, 4/17-18/1998	6/27-28/1998	6/26-28/1999	6/24-25/2000	6/30-7/2/2001	3/19-20/2002, 7/10-11/2002	8/21/2003	4/24-26/2004
'SPIT'									12/3-6/2002	1/28-31/2003	
'STNB'		6/26/1997			6/30-7/1/1998						
'ULAU'		6/21-23/1997			6/27-29/1998	6/26-28/1999	6/24-26/2000	6/30-7/2/2001	7/6-8/2002		
'UWEK'	1/22/1997, 2/10-12/1997	6/24-25/1997	9/12/1997	1/9/1998, 1/23/1998	6/27-28/1998	6/26-28/1999	6/27-29/2000	7/3-5/2001			
'UWER'									5/23-24/2002, 12/3-6/2002	1/28-31/2003	4/20/2004, 7/16/2004
'V118'											4/29/2004
'V120'		6/18-19/1997			6/25/1998	6/24/1999	6/22-23/2000	6/5-6/2001	3/20-21/2002, 7/10-11/2002	8/23-25/2003	6/15-16/2004, 9/28-29/2004
'WNGR'	2/19/1997	6/23-24/1997	8/14/1997		6/24,/26/1998	7/1-2/1999	6/21-22/2000	6/29/2001		9/24/2003	7/21/2004, 8/31/2004

Table 4b. Mauna Loa GPS survey benchmarks and occupation dates								
Code	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
'133T'	6/5/1997	5/28-29/1998	5/26/1999	5/9/2000	6/19/2001	4/4/2002	3/18/2003	6/2-3/2004
'1899'	6/12/1997	6/4-5/1998	5/25/1999	5/24-25/2000	5/30-6/1/2001	7/2-24/2002	3/12-13/2003	7/1-2/2004
'1950'		5/31/1998	5/28/1999	5/12/2000	6/22/2001	4/4-5/2002	3/20/2003	6/4/2004
'49FL'	6/7-9/1997	5/31/1998	5/28/1999	5/12/2000	6/22/2001	4/5/2002	3/20/2003	6/4/2004
'51FL'	6/5/1997	5/28-29/1998	5/26/1999	5/10/2000	6/20/2001	4/3/2002, 9/12/2002	3/19/2003	6/3/2004
'75FL'	6/6/1997	5/30/1998	5/27/1999	5/11/2000	6/21/2001	4/4/2002, 9/12/2002	3/19/2003	6/3/2004
'923_'		5/31/1998	5/28/1999	5/12/2000	6/22/2001	4/5/2002	3/20/2003	6/4/2004
'AIN2'	6/7-9/1997	5/30/1998	5/27/1999	5/11/2000	6/21/2001	4/4, 9/12-30, 11/1-4/2002		
'AINA'	6/10/1997	6/9-10/1998	5/14/1999	5/13-15/2000	6/23/2001	4/6/2002, 10/8/2002		
'AKLA'	1/28-30/1997	5/13/1998	6/8-9/1999		6/12-13/2001	7/26/2002	4/17-18/2003	
'ALEA'	6/4/1997	5/27/1998	5/25/1999	5/9/2000	6/19/2001	4/2/2002, 9/12/2002	3/18/2003	9/22-24/2004
'BRSH'	6/4/1997	5/27/1998	5/25/1999	5/9/2000	6/19/2001	4/3/2002	3/18/2003	6/2/2004
'ELEK'	6/10/1997	6/1-2/1998	5/29/1999	5/13-15/2000	6/23/2001	4/6/2002	3/21/2003	6/4/2004
'ELER'	6/7-9/1997	6/1-2/1998	7/10-12/1999					
'ENDR'	6/5/1997	5/27/1998, 6/18/1998	6/2/1999					
'HINA'	1/28-30/1997	5/13/1998	6/8-9/1999		6/12-13/2001		4/17/2003	
'HONM'		5/31/1998	5/28/1999	5/12/2000	6/22/2001	4/5/2002	3/20/2003	6/4/2004
'KFAS'	6/10/1997	6/1-2/1998	5/29/1999	5/13-15/2000	6/23/2001	4/6/2002, 11/23-24/2002	3/21/2003	9/22-24/2004
'KFLT'		6/9-10/1998	5/14/1999			7/24-25/2002	3/11/2003	
'KULN'	6/24-25/1997	6/30-7/1/1998	6/29-30/1999	7/1-3/2000	5/31-6/1/2001		10/10-12/2003	12/21-22/2004

Table 4b continued. Mauna Loa GPS survey benchmarks and occupation dates								
Code	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
'KULU'	6/10/1997	6/1-2/1998	5/29/1999	5/13-14/2000	6/23/2001	4/6/2002, 11/23-24/2002	3/21/2003	6/4/2004
'LACY'	6/12-13/1997	6/3-5/1998	6/9-11/1999	5/25-26/2000	6/6-7/2001	7/24-25/2002	3/11-12/2003	6/16-17/2004
'LKAO'	6/4/1997		5/25/1999					
'LUAK'	4/29/1997						4/17-18/2003	
'ML1_'	6/6/1997	5/30/1998	5/27/1999					
'ML8_'	6/10/1997	6/1-2/1998	5/28/1999	5/12/2000	6/22/2001	4/6/2002, 11/23-24/2002	3/21/2003	
'MLCE'	6/7-9/1997	5/30/1998	5/27/1999	5/11/2000	6/21/2001	4/4/2002	3/21/2003	6/3/2004
'MLO_'	6/4-6/1997	6/4-5/1998	5/26/1999	5/24-25/2000	5/30-6/1/2001	7/23-24/2002. 10/10-11/2002		
'MLST'	1/16-17/1997, 2/10-12/1997							
'MLSW'		5/30/1998	5/26/1999	5/10/2000	6/20/2001	4/3/2002, 11/23-24/2002	3/19/2003	6/3/2004
'MOAU'		5/13/1998	4/28-29/1999		6/12-13/2001	7/26/2002	4/17-18/2003	
'MOKU'	6/10/1997	6/1-2/1998	5/29/1999	5/13-15/2000	6/23/2001	4/4/2002	3/21/2003	6/4/2004
'NAAL'	4/29/1997		6/8-9/1999		6/13-14/2001	7/26/2002	3/26-27/2003	
'NOWR'		5/27/1998	5/25/1999	5/9/2000	6/19/2001	4/2/2002	3/18/2003	6/2/2004
'NWML'	6/4/1997	5/27/1998	5/25/1999	5/9/2000	6/19/2001	4/2/2002	3/18/2003	6/2/2004
'P103'	6/12/1997	6/4-5/1998	7/1-2/1999	5/24-25/2000	5/30-31/2001	7/23-24/2002	3/12-13/2003	7/1-2/2004
'PLUU'		5/12-14/1998	5/1-3/1999		6/6-7/2001	7/25/2002	3/26-27/2003	6/16-17/2004
'POHO'	4/29/1997		6/8-9/1999		7/10-12/2001		5/21-23/2003	6/22-23/2004
'POUO'	6/5/1997	5/28-29/1998	5/26/1999	5/10/2000	6/20/2001	4/3/2002		6/3/2004
'REDC'	6/7-9/1997	5/31/1998	5/28/1999	5/11/2000	6/21/2001	4/5/2002, 9/12/2002	3/20/2003	6/4/2004
'SELH'	6/7-9/1997	5/31/1998	5/27/1999	5/11/2000	6/21/2001	4/4/2002	3/20/2003	6/3/2004
'V134'	6/5/1997	5/28-29/1998	5/26/1999	5/10/2000	6/20/2001	4/3/2002	3/19/2003	6/3/2004
'VANC'	6/12/1997	6/4-5/1998	5/26/1999	5/24-25/2000	5/30-6/1/2001	7/23-24/2002	3/12-13/2003	7/1-2/2004

Table 4b continued. Mauna Loa GPS survey benchmarks and occupation dates								
Code	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
'VENT'	6/4/1997	6/18/1998	5/25/1999	5/9/2000	6/19/2001	4/2/2002	3/27-28/2003	6/2/2004
'VO92'	6/6/1997	5/30/1998	5/27/1999	5/10/2000	6/20/2001	4/4/2002	3/18/2003	6/2/2004
'WAIH'		5/13/1998	4/28-29/1999		6/12-13/2001	7/26/2002	4/17-18/2003	
'WMLS'	6/6/1997	5/28/1998	5/26/1999	5/10/2000	6/20/2001	4/2/2002	3/19/2003	6/3/2004
WEST MAUNA LOA								
'HONO'			6/17/1999					
'HONR'	4/29/1997		6/17/1999		7/11/2001		5/20-21/2003	
KEAL	4/30-5-1/1997		6/16/1999		7/10-12/2001		5/22-23/2003	
'KEEI'	4/30/1997		6/17/1999		7/11/2001		5/20,22/2003	
'KNKI'	4/30/1997		6/16/1999		7/11/2001		5/22/2003	
'KRCN'	4/30/1997		6/16/1999		7/11/2001		5/20,22/2003	
'MILO'	4/29/1997		6/15/1999		7/10/2001		5/21/2003	
'YEHP'	4/29/1997		6/16-17/1999		7/6/2001		5/22-23/2003	
'YHP3'					7/6/2001		5/22/2003	

Table 4c. Hualalai, Maui and miscellaneous GPS survey benchmarks and occupation dates								
Code	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
HUALALAI								
'1800'		4/2/1998			8/8-9/2001		6/18-19/2003	
'HALE'		4/2/1998			8/9/2001		6/19/2003	
'HOLU'	5/1-2/1997				8/8-9/2001		6/18/2003	
'IKAA'		4/1/1998			8/8/2001		6/18/2003	
'JUDD'		4/1/1998			8/8/2001			
'KEHU'		4/2/1998			8/8-9/2001		6/18-19/2003	
'KIPA'		4/3/1998			8/9/2001		6/19/2003	
'LOHA'					8/8/2001		6/18/2003	
'MAAU'		4/1/1998			8/9/2001		6/19/2003	
'MALE'	5/2/1997	4/3/1998			8/10/2001		6/20/2003	
'MORC'		4/1/1998			8/9/2001		6/20/2003	
'NCAB'					8/10/2001		6/20/2003	
'NOHO'					8/8/2001		6/19/2003	
'WAIA'	5/2/1997	4/3/1998					6/18/2003	
MAUI								
'HAIL'	7/25/1997							
'HANA'	7/24/1997							
'HKHI'	7/23-25/1997							
KHUA	7/25/1997							
'KNAE'	7/24/1997							
'KOLE'	7/22-25/1997	4/21-25/1998						
'LEIE'	7/24/1997							
'LOOK'	7/22/1997							
'LUAL'	7/22/1997							
'NIAN'	7/22-23/1997							
'POLI'	7/25/1997							
'PUUI'	7/22-23/1997							
MISCELLANEOUS								
'BLDR'	1/16-17, 6/12, 9/11-12/1997	6/5/1998, 7/9-10/1998	5/27/1999, 7/1-2/1999	5/24-25/2000	5/30-31/2001	7/2-243/2002	3/12-13/2003	7/1-2/2004
'HP7_'	3/19/1997, 6/24-25/1997	6/30-7/1/1998	6/16-17/1999	6/26-27/2000	7/10-12/2001	7/15-17//2002	9/25-26/2003	12-16-17/2004
KALK'	4/29-5-2/1997	4/1-3/1998	6/16-17/1999		7/10-12/2001		5/21/2003	
'MKEA'	6/24-25/1997, 9/11-12/1997	7/16-17/1998						
'RLYM'	6/23-24/1997	6/25,30/1998						

Table 5a. 1997-2002 continuous station velocities, in meters

Station	East	North	Up	N sigma	E sigma	U sigma
Kilauea: July 01 1997 to Dec 01 2001						
AHUP	0.0186	-0.0125	-0.0489	0.0002	0.0002	0.0009
GOPM	0.0285	-0.0624	0.0136	0.0002	0.0002	0.0008
HALP	0.0068	-0.0201	0.0008	0.0010	0.0008	0.0035
HILO	0.0008	0.0017	0.0022	0.0004	0.0003	0.0011
HOLE	0.0352	-0.0549	0.0200	0.0003	0.0003	0.0011
KAEP	0.0351	-0.0595	0.0193	0.0003	0.0002	0.0008
KOSM	0.0384	-0.0173	-0.0343	0.0003	0.0002	0.0010
KTPM	0.0313	-0.0367	0.0119	0.0002	0.0002	0.0008
MANE	0.0213	-0.0226	-0.0044	0.0003	0.0002	0.0010
MLPM	0.0033	0.0001	0.0008	0.0004	0.0004	0.0012
NUPM	0.0012	-0.0287	-0.0146	0.0002	0.0002	0.0008
PGF1	0.0148	-0.0209	0.0077	0.0003	0.0002	0.0008
PGF2	0.0354	-0.0657	0.0156	0.0003	0.0002	0.0008
PGF3	0.0249	-0.0557	0.0162	0.0003	0.0002	0.0009
PGF4	0.0260	-0.0566	0.0160	0.0003	0.0002	0.0008
PGF5	0.0181	-0.0374	0.0128	0.0002	0.0002	0.0008
PGF6	0.0133	-0.0252	0.0089	0.0003	0.0002	0.0008
UWEV	0.0087	-0.0151	-0.0096	0.0002	0.0002	0.0009
WAOP	0.0016	-0.0105	-0.0030	0.0010	0.0008	0.0034
Mauna Loa: Jan 01 1997 to May 01 2002						
ELEP	0.0068	-0.0057	-0.0022	0.0003	0.0003	0.0011
MLSP	0.0056	-0.0034	-0.0119	0.0004	0.0003	0.0013
MOKP	0.0090	-0.0077	-0.0077	0.0003	0.0003	0.0012
Mauna Kea velocity removed: this estimate from 1997 through 2004						
MKPM	-0.0632	0.0333	-0.00168	0.00000	0.00001	0.00006

Table 5b. 2002-2004 continuous station velocities, in meters

Station	East	North	Up	N sigma	E sigma	U sigma
Kilauea: Dec 01 2001 to Dec 31 2004						
AHUP	0.0158	-0.0281	-0.0242	0.0004	0.0004	0.0016
GOPM	0.0211	-0.0471	0.0130	0.0005	0.0004	0.0017
HALR	0.0157	-0.0300	0.0222	0.0009	0.0008	0.0033
HILO	-0.0016	0.0012	0.0020	0.0004	0.0004	0.0014
HOLE	0.0284	-0.0522	0.0215	0.0005	0.0004	0.0018
KAEP	0.0283	-0.0483	0.0169	0.0004	0.0004	0.0015
KOSM	0.0260	-0.0204	-0.0241	0.0004	0.0004	0.0015
KTPM	0.0193	-0.0387	0.0173	0.0004	0.0003	0.0015
MANE	0.0152	-0.0284	-0.0021	0.0004	0.0004	0.0017
MLPM	0.0014	-0.0004	0.0011	0.0004	0.0004	0.0020
NUPM	-0.0026	-0.0132	0.0009	0.0004	0.0003	0.0014
PGF1	0.0101	-0.0229	0.0055	0.0004	0.0004	0.0015
PGF2	0.0219	-0.0478	0.0166	0.0005	0.0004	0.0016
PGF3	0.0159	-0.0474	0.0170	0.0004	0.0004	0.0015
PGF4	0.0158	-0.0472	0.0166	0.0004	0.0004	0.0016
PGF5	0.0117	-0.0373	0.0061	0.0007	0.0006	0.0024
PGF6	0.0084	-0.0276	0.0063	0.0005	0.0004	0.0016
UWEV	-0.0054	0.0019	0.0056	0.0004	0.0003	0.0014
WAOP	-0.0030	0.0038	0.0093	0.0005	0.0004	0.0018
Mauna Loa: May 01 2002 to Dec 31 2004						
ELEP	0.0304	-0.0111	0.0087	0.0005	0.0004	0.0017
MLSP	-0.0059	-0.0111	0.0261	0.0005	0.0004	0.0016
MOKP	-0.0089	0.0059	0.0187	0.0005	0.0004	0.0017
AINP	0.0148	-0.0111	0.0009	0.0008	0.0007	0.0029
PAT2	0.0317	-0.0307	0.0293	0.0012	0.0011	0.0051
STEP	-0.0017	0.0000	0.0050	0.0007	0.0007	0.0029
Mauna Kea velocity removed: this estimate from 1997 through 2004						
MKPM	-0.0632	0.0333	-0.00168	0.00000	0.00001	0.00006

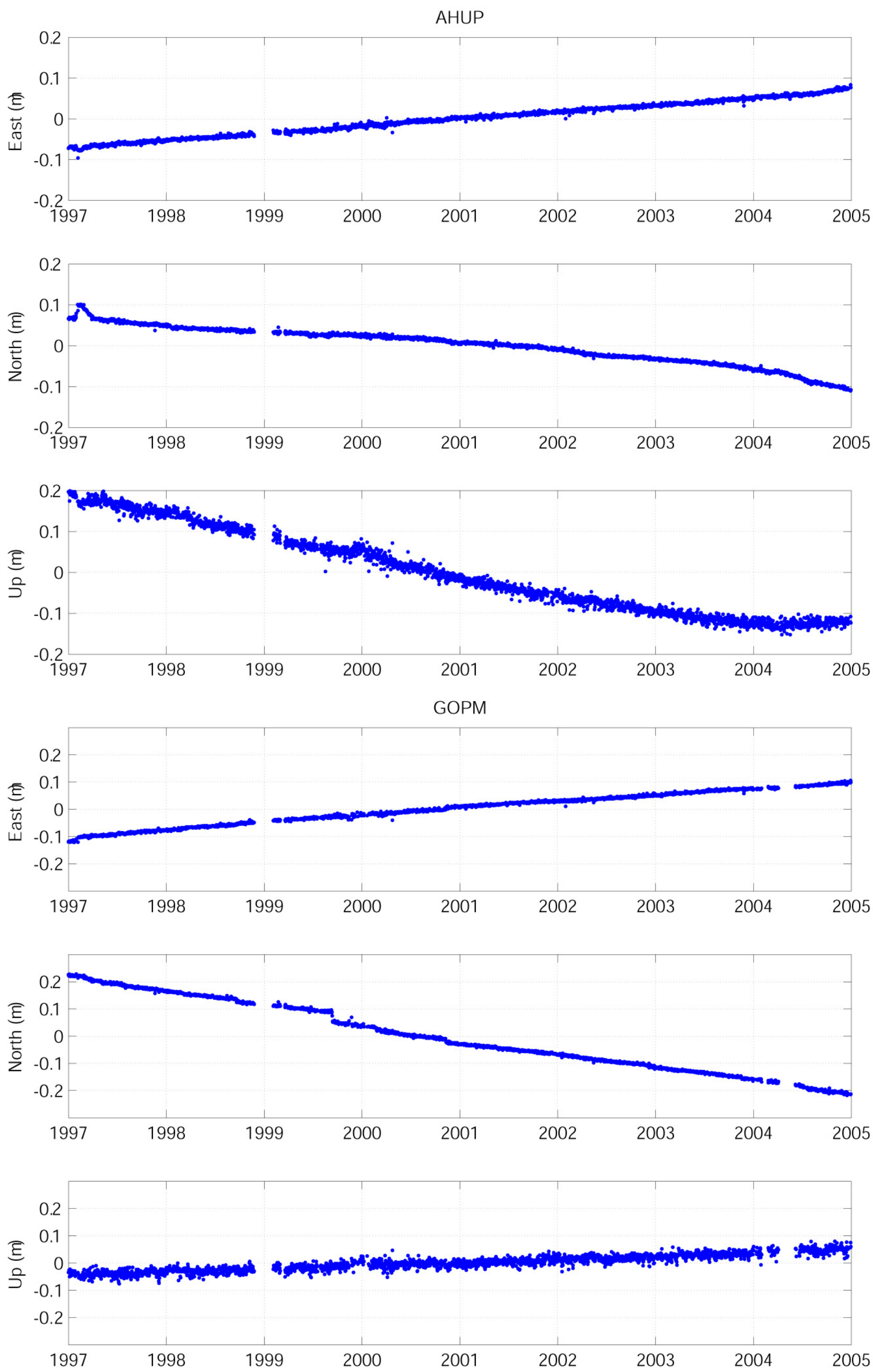

Figure 5a. Time series of continuously recording sites AHUP, GOPM.

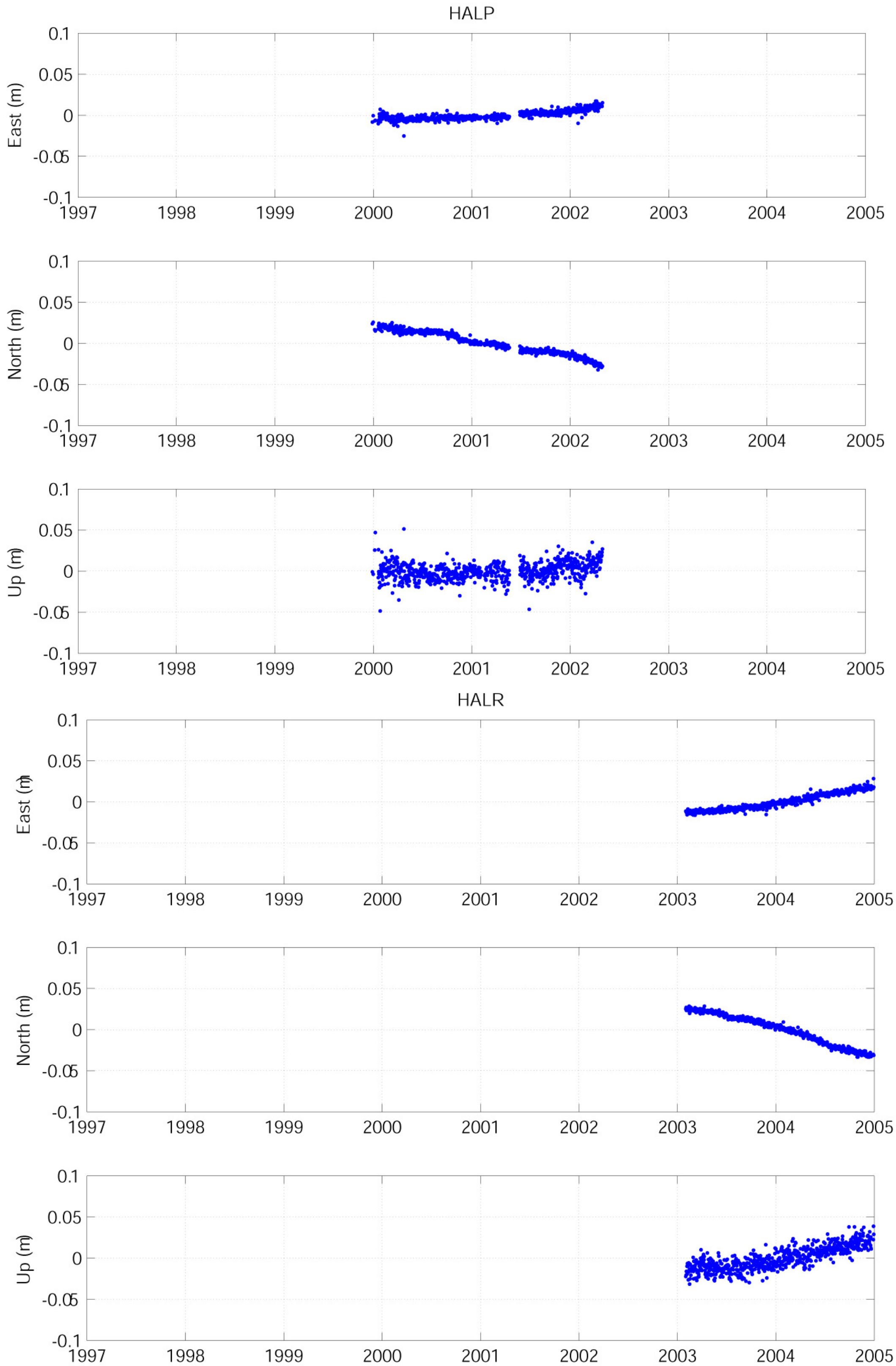

Figure 5b. Time series of continuously recording sites HALP, HALR.

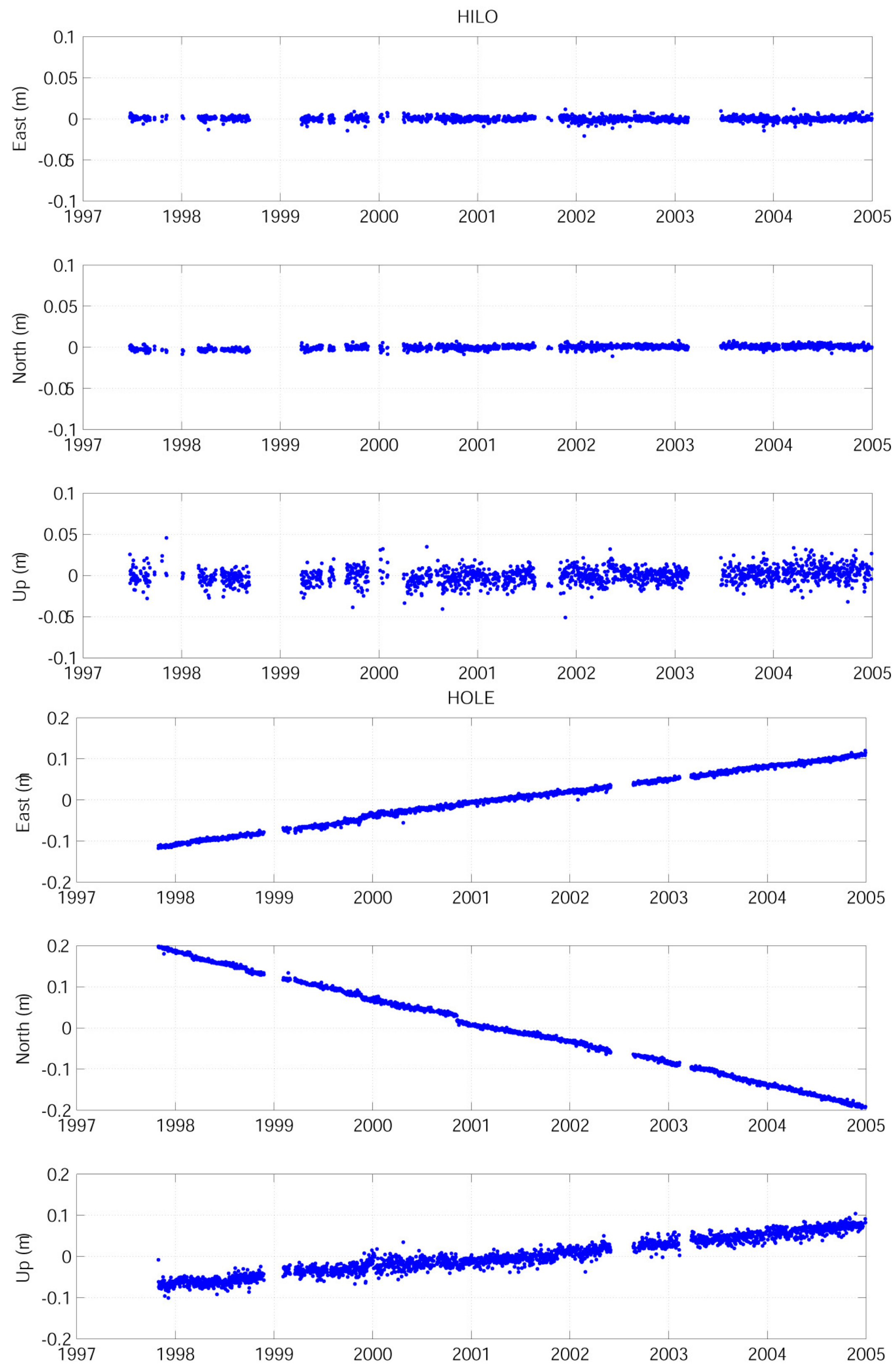

Figure 5c. Time series of continuously recording sites HILO, HOLE.

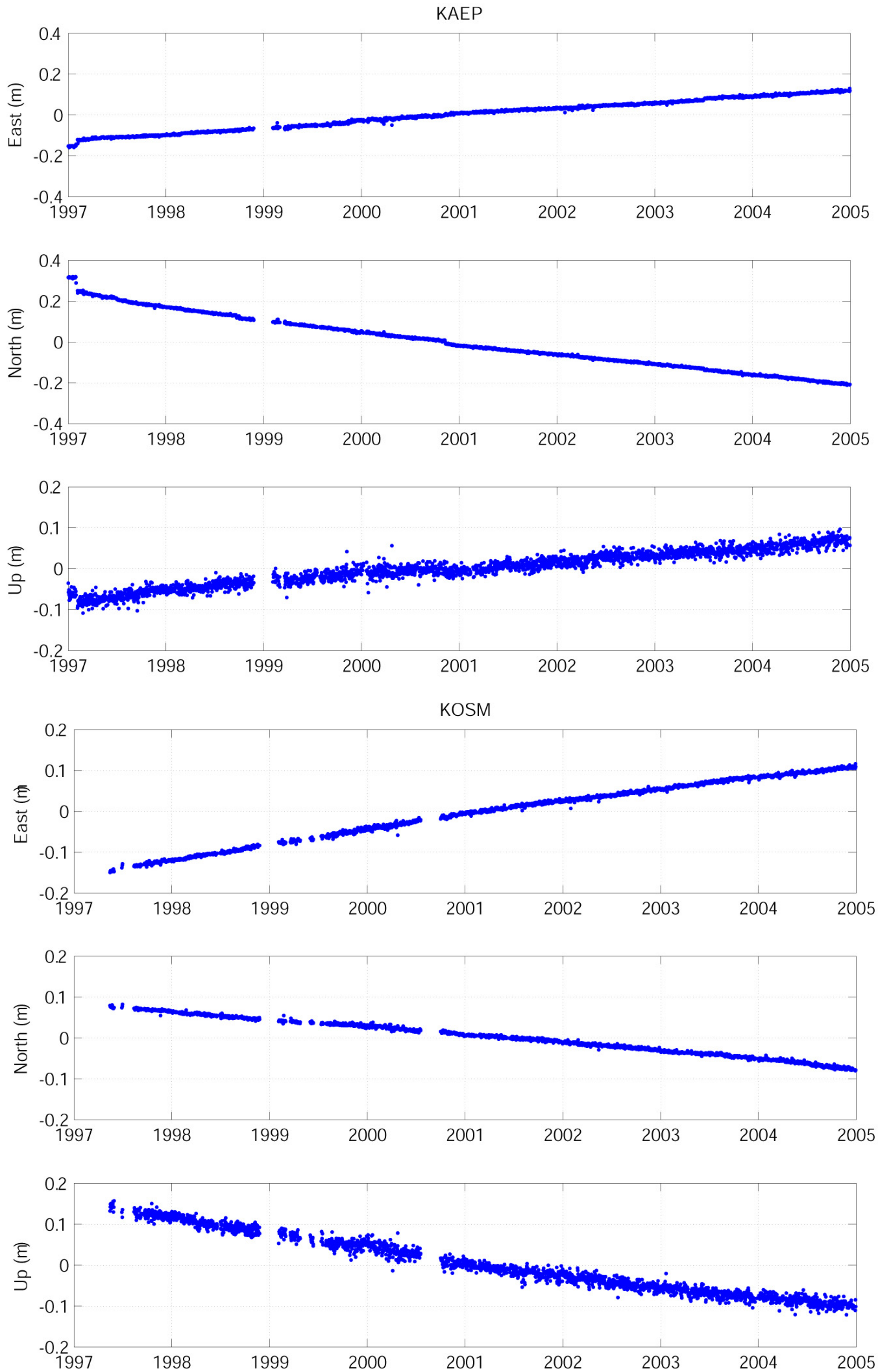

Figure 5d. Time series of continuously recording sites KAEP, KOSM.

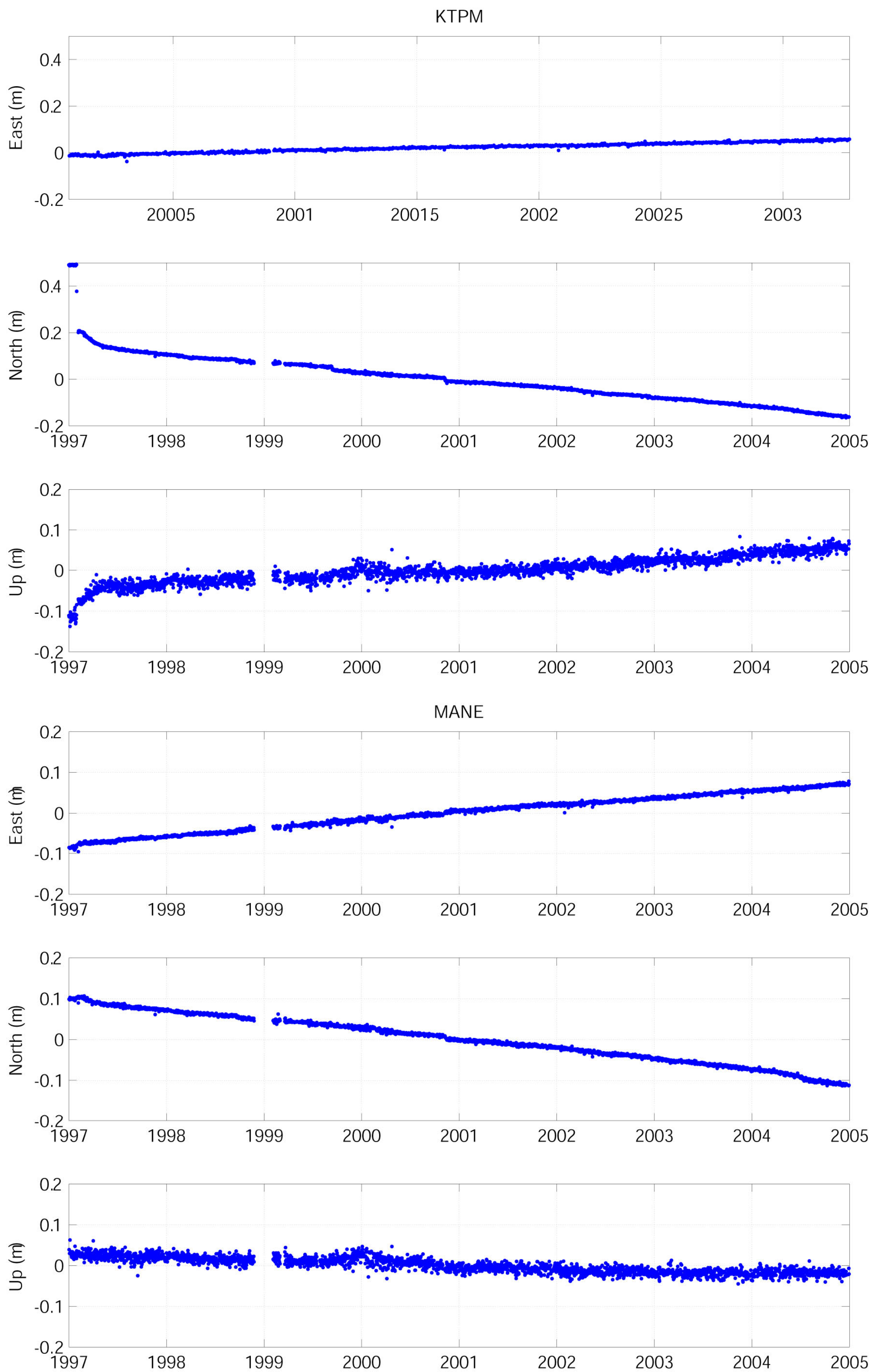

Figure 5e. Time series of continuously recording sites KTPM, MANE.

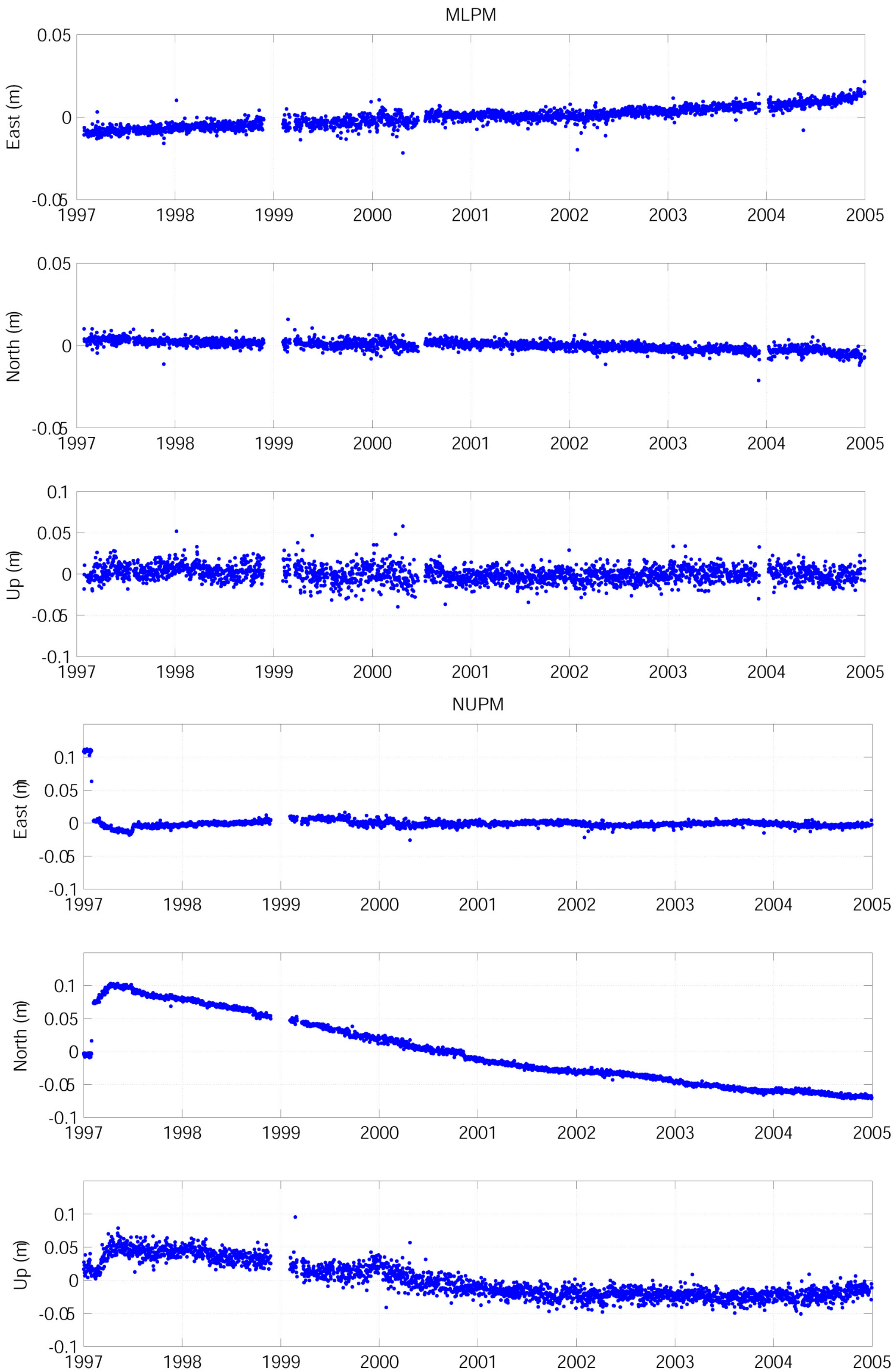

Figure 5f. Time series of continuously recording sites MLPM, NUPM.

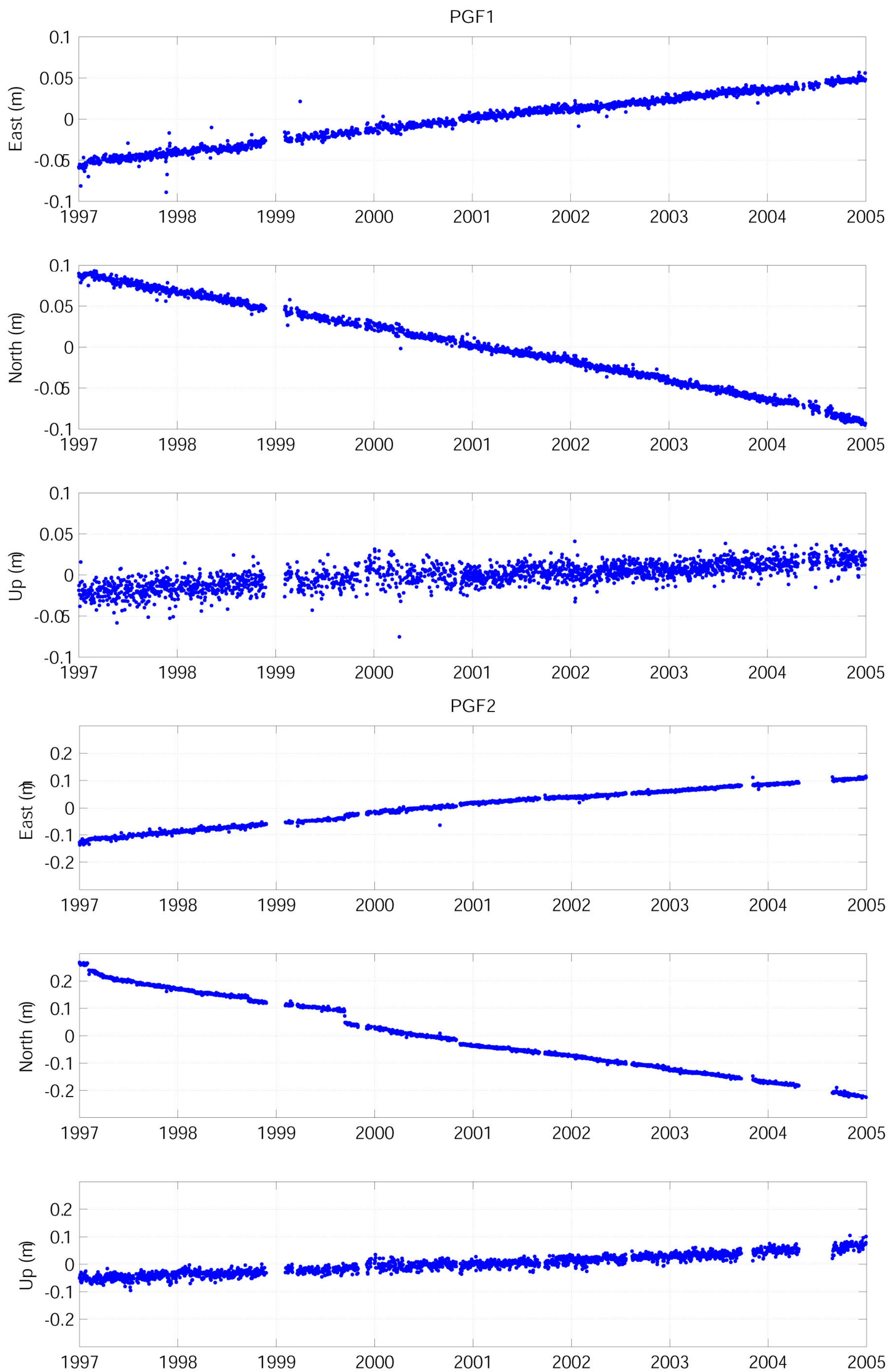

Figure 5g. Time series of continuously recording sites PGF1, PGF2.

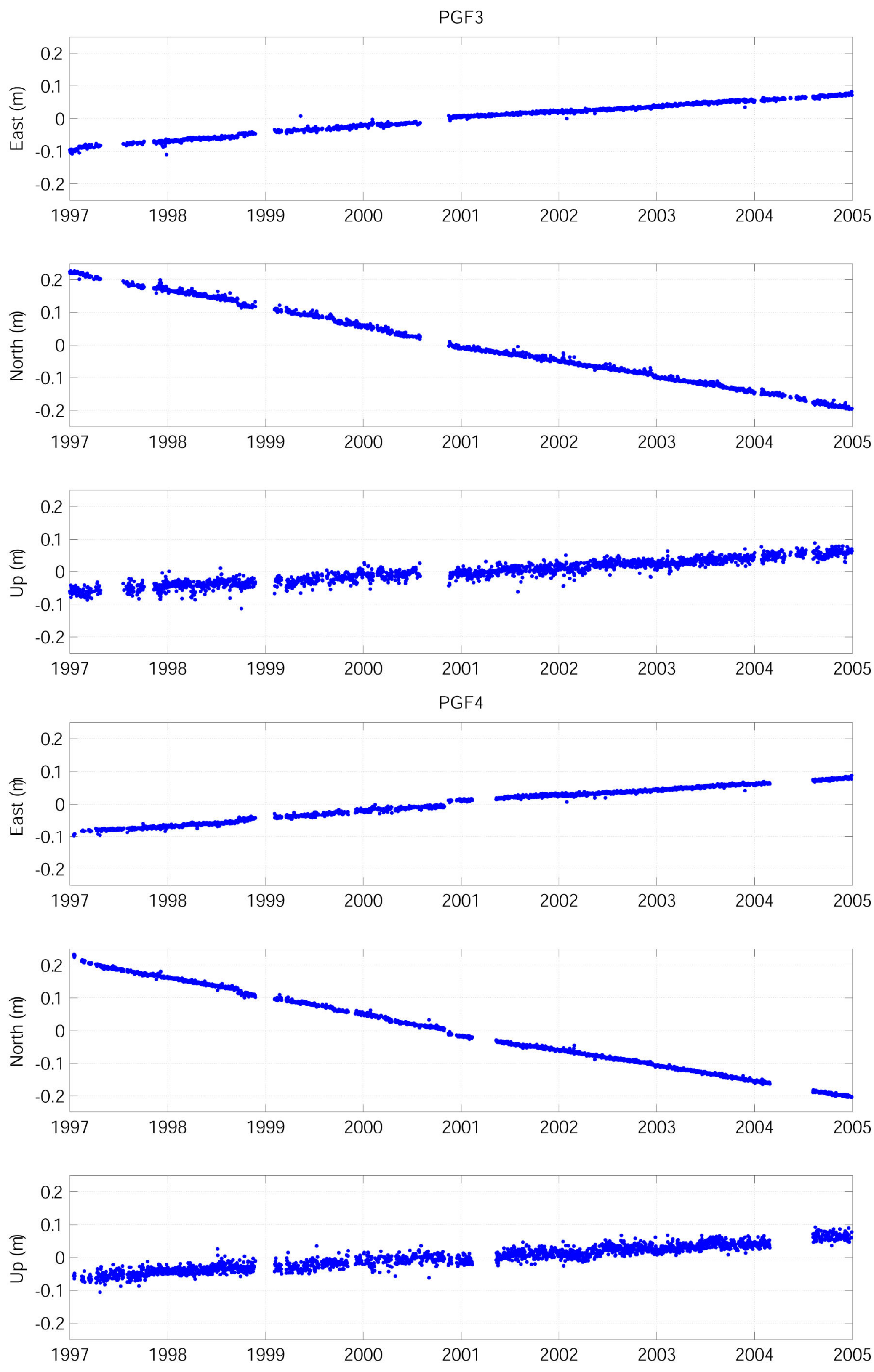

Figure 5h. Time series of continuously recording sites PGF3, PGF4.

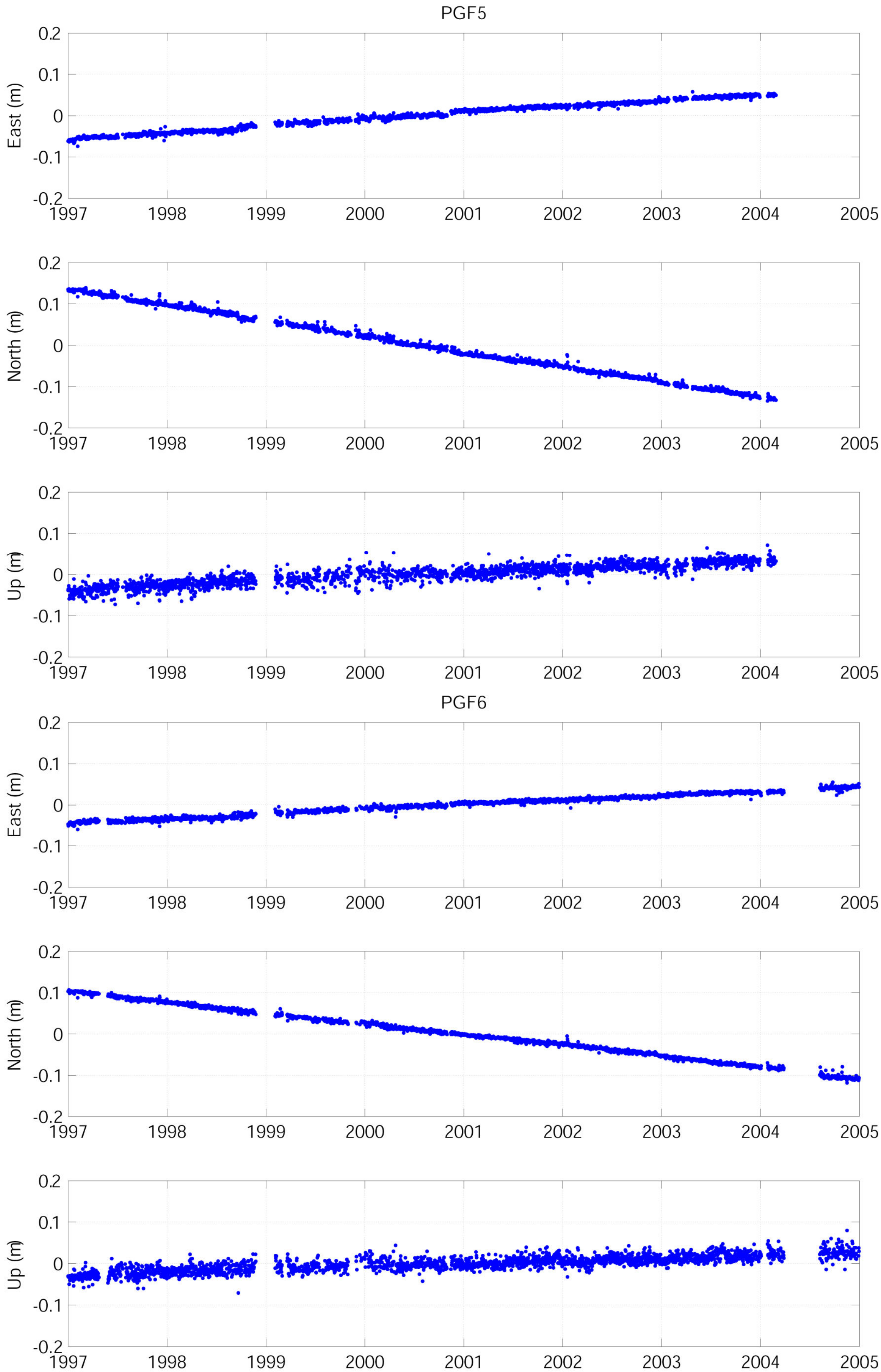

Figure 5i. Time series of continuously recording sites PGF5, PGF6.

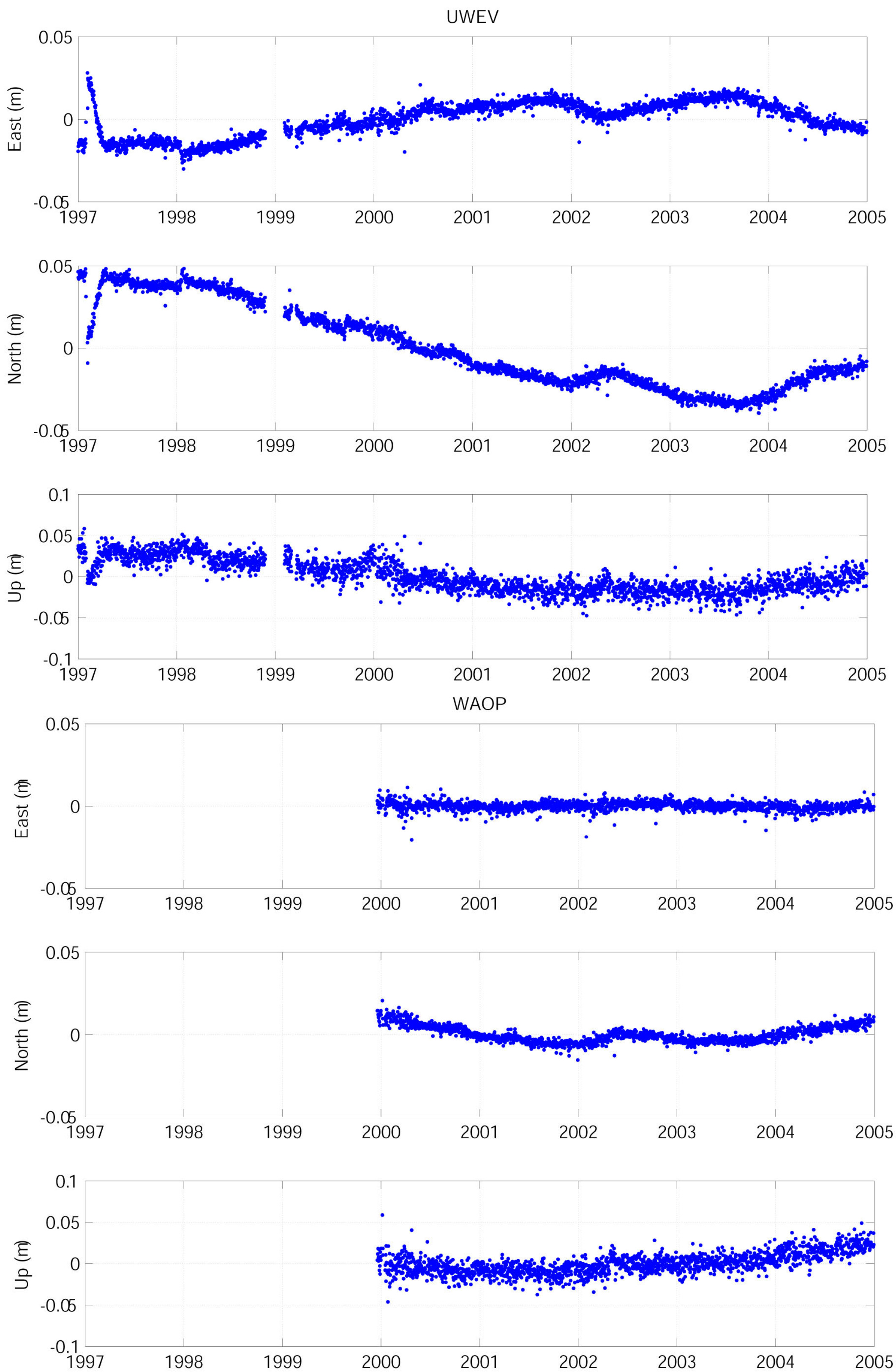

Figure 5j. Time series of continuously recording sites UWEV, WAOP.

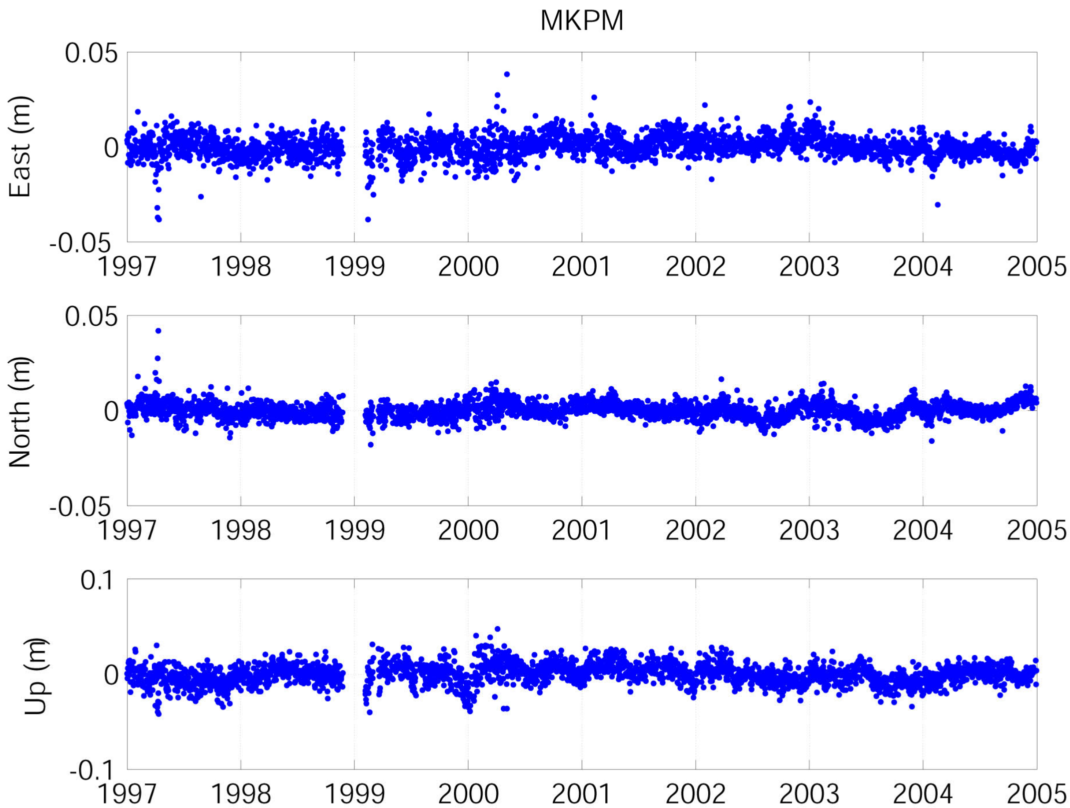

Figure 5k. Time series of continuously recording site MKPM.

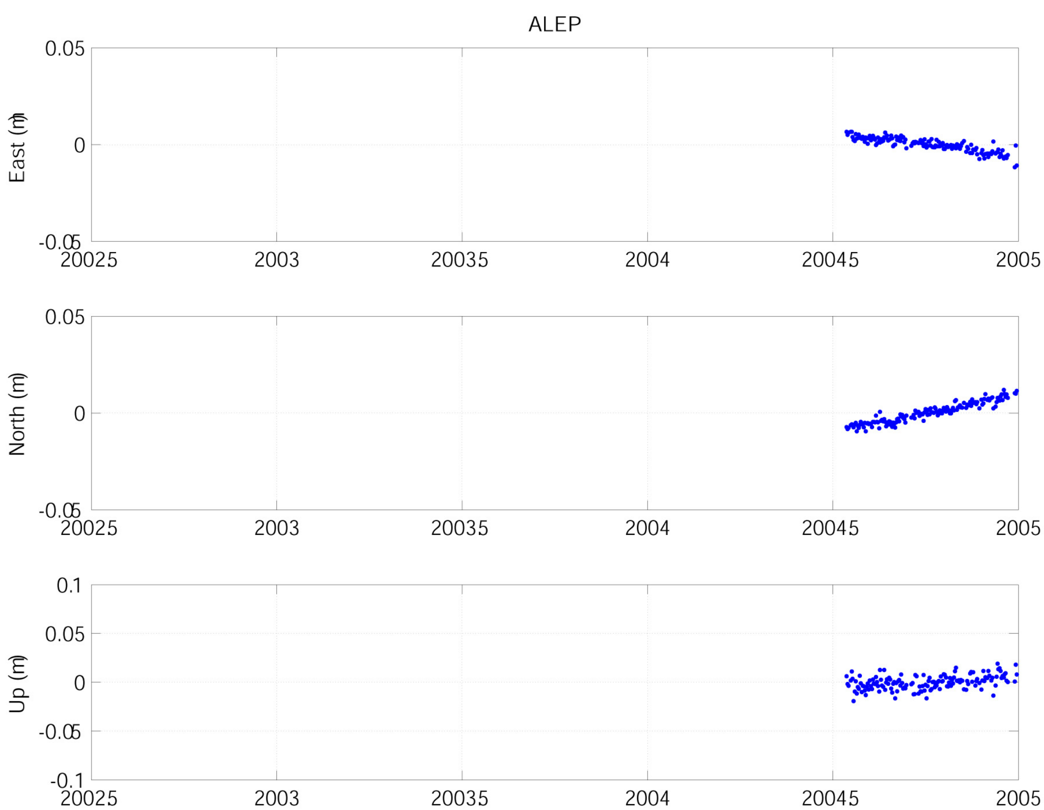

Figure 5l. Time series of continuously recording sites AINP, ALEP.

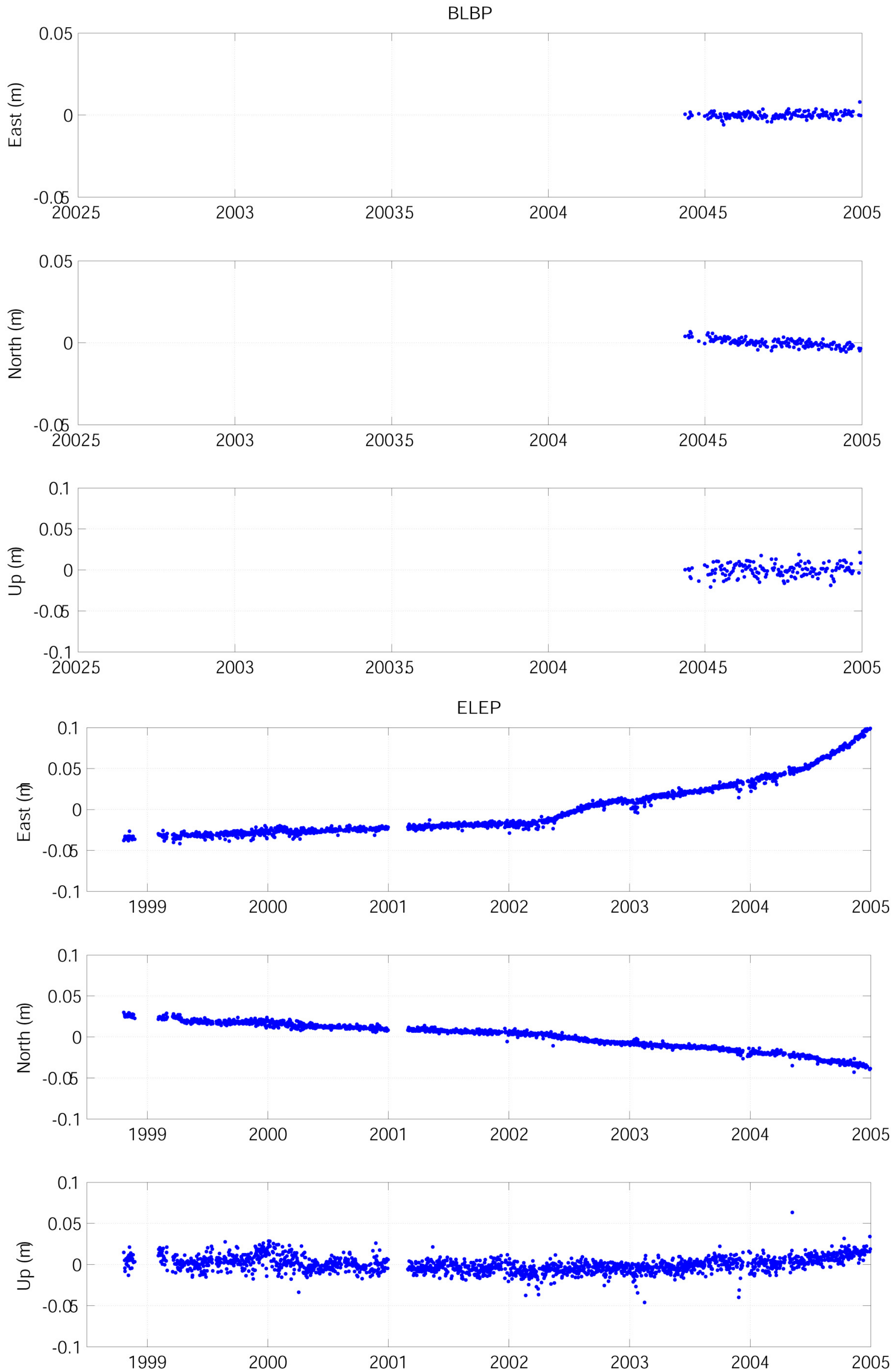

Figure 5m. Time series of continuously recording sites BLBP, ELEP.

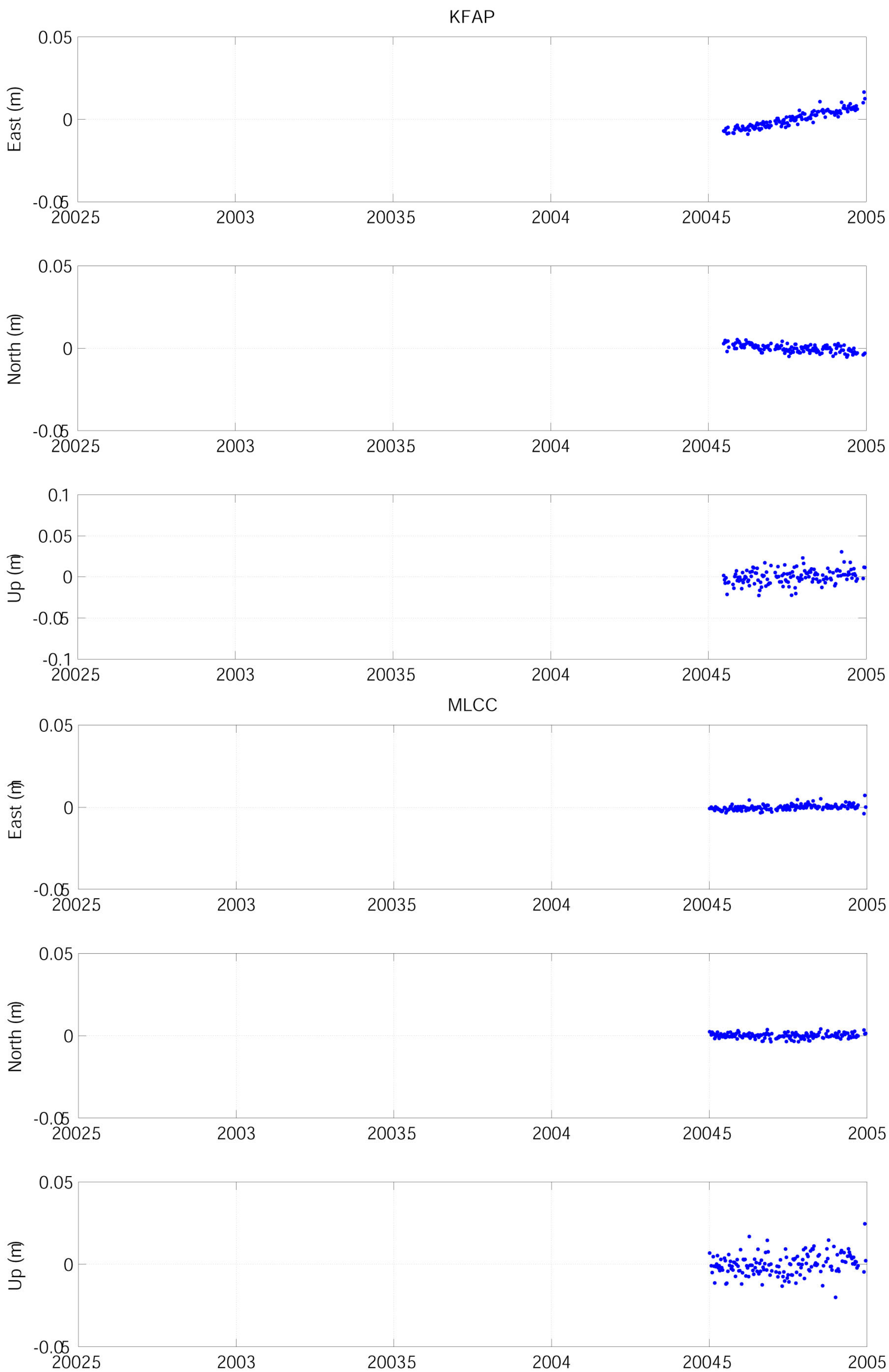

Figure 5n. Time series of continuously recording sites KFAP, MLCC.

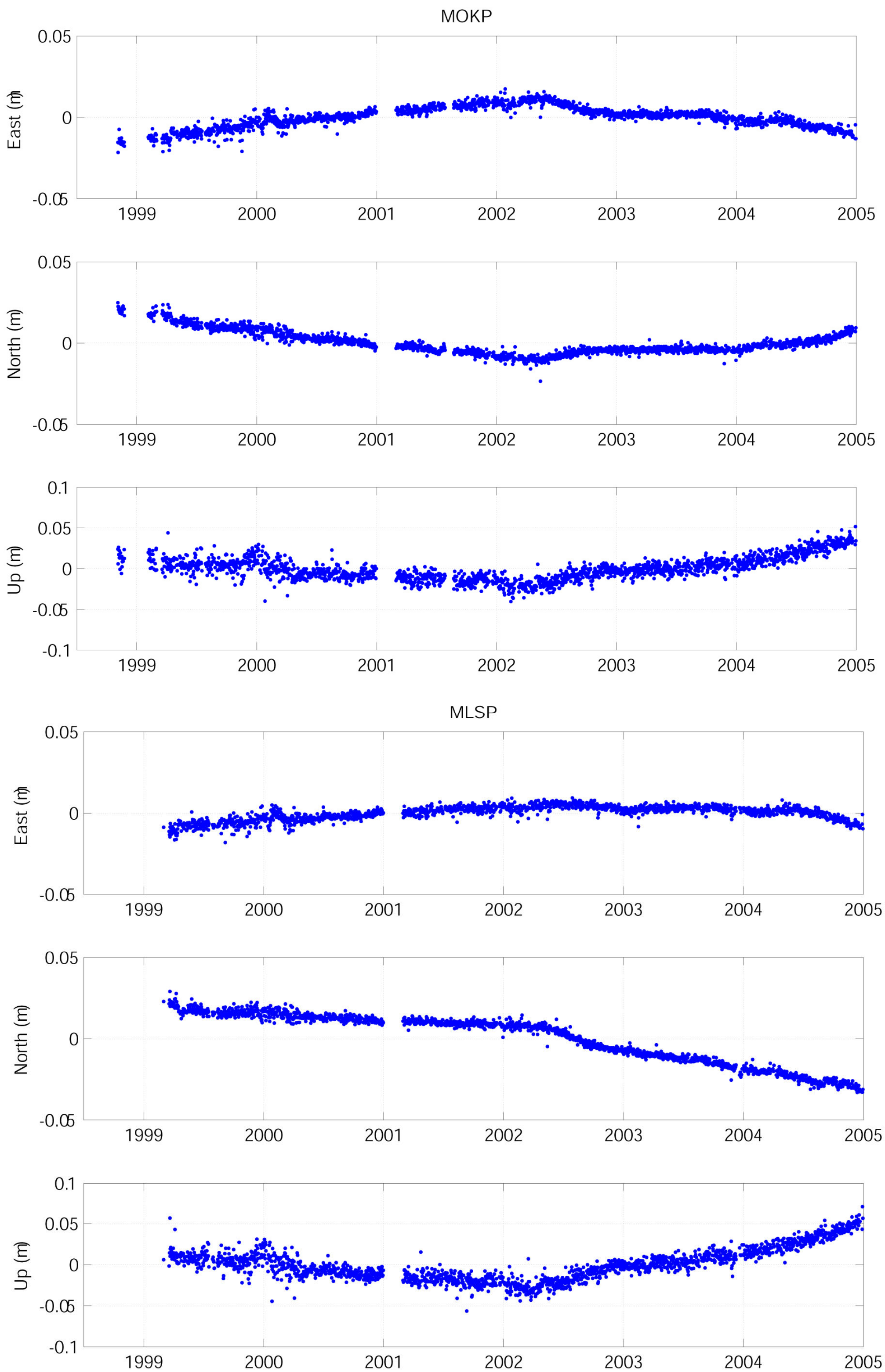

Figure 5o. Time series of continuously recording sites MLSP, MOKP.

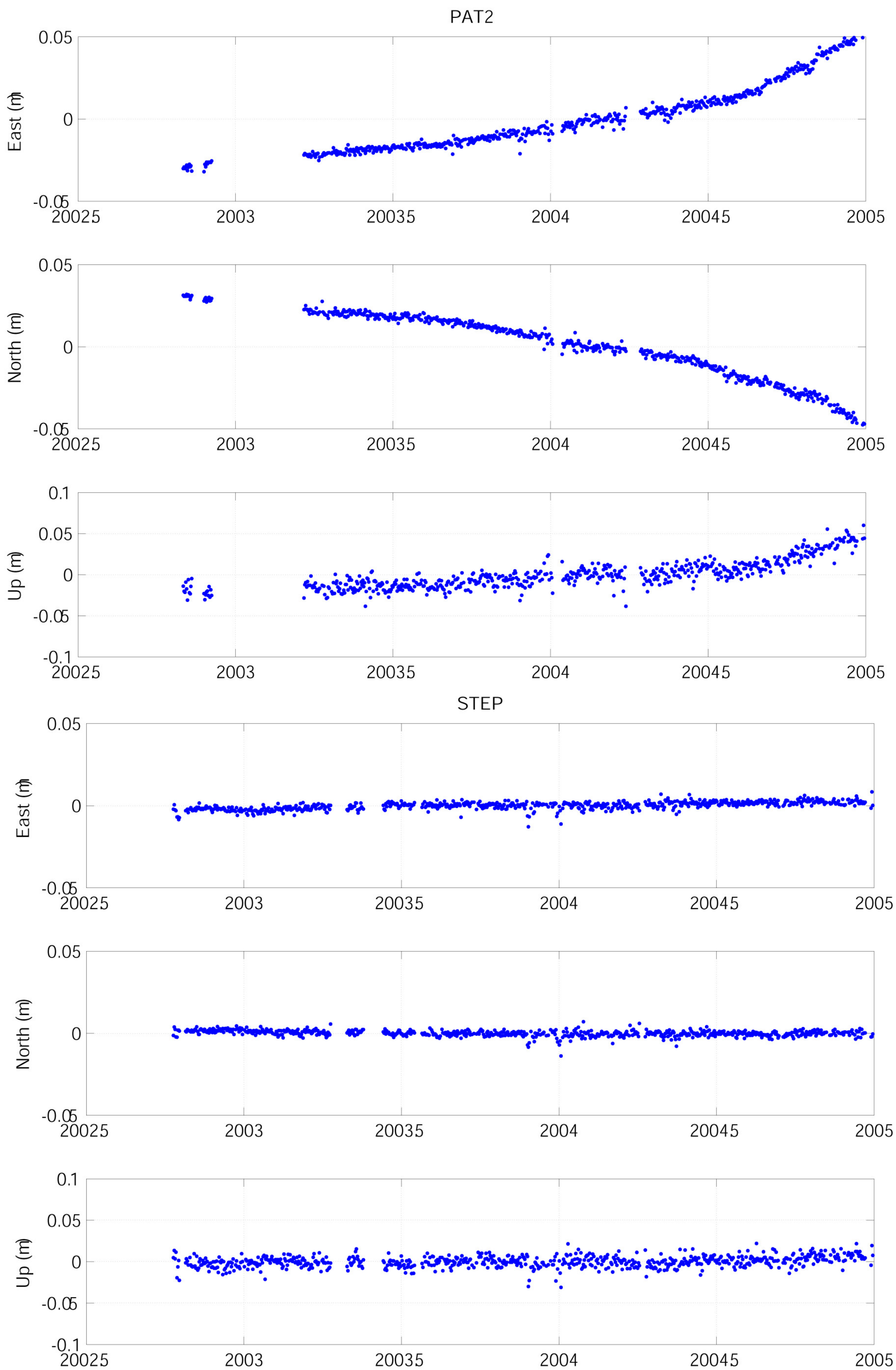

Figure 5p. Time series of continuously recording sites PAT2, STEP.

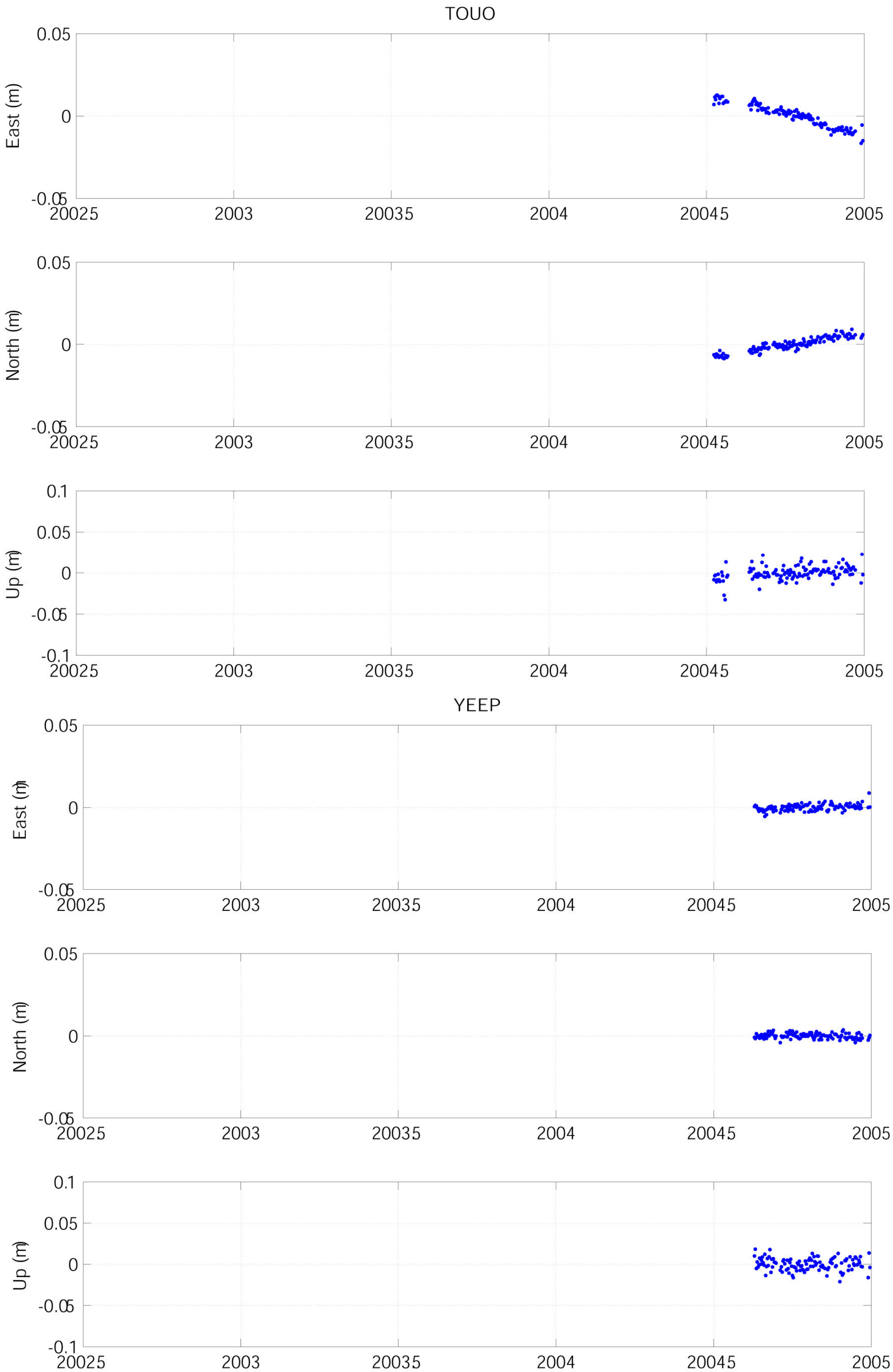

Figure 5q. Time series of continuously recording sites TOUO, YEEP.

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