Kobe earthquake monitoring – real time geodetic networking

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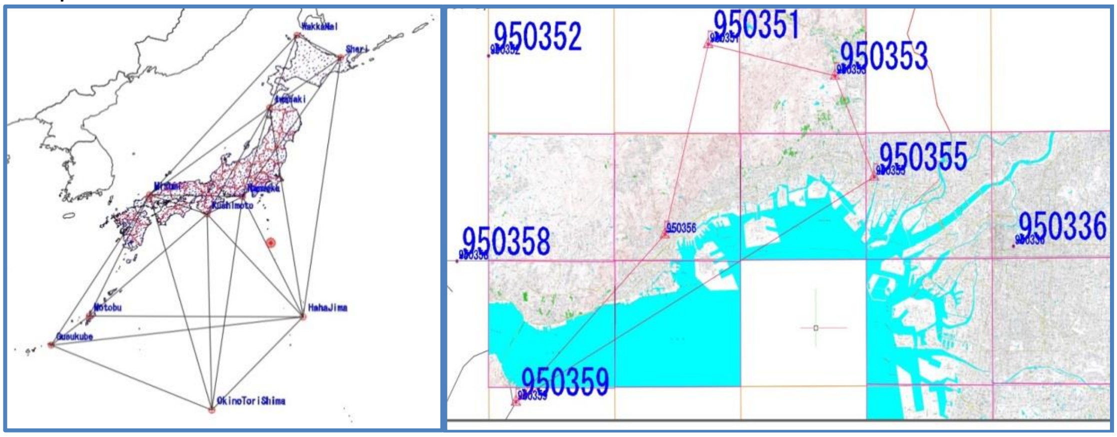
Key words: *Kobe GNSS Networking; GEONAP; Parameter Estimation satellite surveying; Helicopter photogrammetry*

ABSTRACT

In 1995 Kobe earthquake innovated geodetic networking with GPS observations, and in 2018 Geospatial Information Authority of Japan (GSI) has been monitoring more than 1300 electronic control points nationwide in Japan. GeoNet introduced Parameter Estimation approach in geodetic networking using GEONAP since 2000, and now proceeded to integrated geodetic networking among GNSS, levelling and gravity measurement, using PANDA. Kobe harbor is now preparing for tsunami disaster caused by Nankai Trough Earthquake. For this purpose GeoNet and Kobe University set up Kobe pentagonal reference stations for 1 second adjustment monitoring (Kobe GNSS networking). As for the preparatory procedures, GEONAP nationwide network adjustment and Kumamoto and Kyoto-Osaka regional adjustments were successfully completed along with active faults lines. As deformation monitoring is closely related with cadastral system for reconstruction projects, the author presented provisional specifications for public cadastral survey projects with 4 major approaches of GNSS networking and helicopter and satellite photogrammetry. Kobe GNSS networking could confirm an authentic specification for earthquake prediction and alert residents with substantial measure against expected natural disasters.



Introduction

Japan Electronic Control Points (ECPs) of 1300 weatherproof reference stations by Japan GSI have been observed since 1994 nationwide for earthquake prediction and geodetic control points networking. UN-GGRF initiative requires precise national geodetic networking. German DREF networking adjusted GNSS, levelling and gravimetric networks with several mm level accuracy in 2010. As we have been using static and mobile GNSS surveying of parameter estimation approach since 1999, we proceed to geodetic networking of 3 components of plate tectonic monitoring with real time observation-adjustment solution supported with the most powerful super computer environment in Kobe city. As the model area for real time observation, Kobe University; maritime science campus area is now selected for both high tide and tsunami disaster area innermost part of Osaka bay.

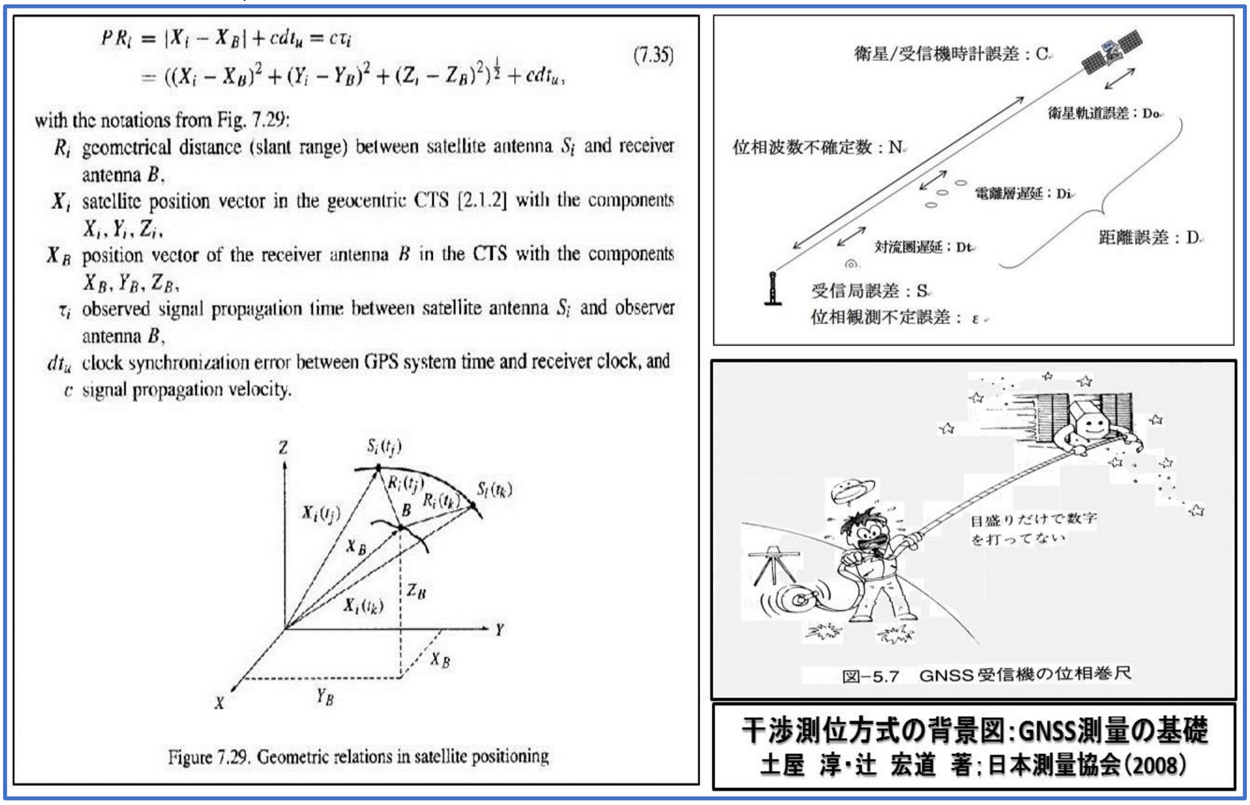
Practical applications are not only earthquake-tsunami prediction but 3D cadastral survey for preparatory and reconstruction public projects, as we have learned from 1995 Kobe earthquake. For this purpose we apply helicopter photogrammetry, developing automatic bundle triangulation and camera calibration of digital cameras.

1. IGS-Japan-Kobe-Osaka-Kyoto-1sec; σ =1cm-Earthquake Monitoring on 3D-CAD and CAD-Globe

PARAMETER ESTIMATION ; Satellite Geodesy Dr. G. Seeber (Univ. Hannover; Institute of Geodesy) 2001 and DREF91;1999 gave us the basic procedures for nationwide geodetic networking in Japan.

Fig. 1 Satellite Geodesy - G Seeber and DREF91

In practice, Japanese approach in Satellite Geodesy has been driven by so called "interferometric approach" by The Geospatial Information Authority of Japan (GSI). On the contrary, we have been using Parameter Estimation approach in Satellite Geodesy with observation equations and error parameters as follows;



$$PR_i = |X_i - X_B| + cdt_u = c\tau_i$$
$$= ((X_i - X_B)^2 + (Y_i - Y_B)^2 + (Z_i - Z_B)^2)^{\frac{1}{2}} + cdt_u, \quad (7.35)$$

with the notations from Fig. 7.29:

- R_i geometrical distance (slant range) between satellite antenna S_i and receiver antenna B,
- X_i satellite position vector in the geocentric CTS [2.1.2] with the components X_i, Y_i, Z_i,
- X_B position vector of the receiver antenna B in the CTS with the components X_B, Y_B, Z_B,
- τ_i observed signal propagation time between satellite antenna S_i and observer antenna B,
- dt_u clock synchronization error between GPS system time and receiver clock, and
- c signal propagation velocity.

Figure 7.29. Geometric relations in satellite positioning

Fig. 2 Parameter Estimation approach in Satellite Geodesy and Interferometric approach : Japan GSI

Now we are to establish 3 zonal networking of land- seashore- near trough reference stations of Japanese archipelago as a whole utilizing IGS (International GNSS service)' 500 references as follows;

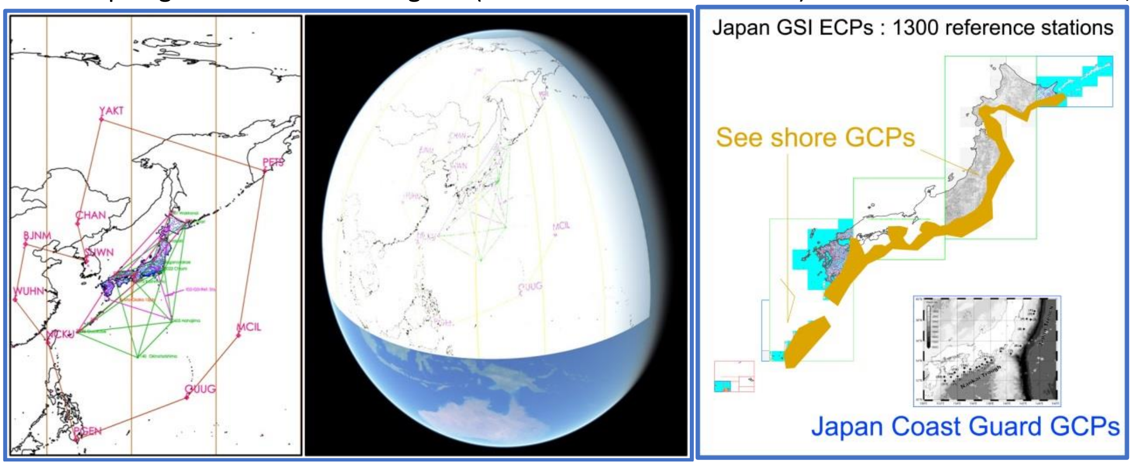


Fig. 3 IGS network on CAD globe and land- see shore- trough reference stations of Japan islands

2. Summary on GEONAP geodetic networking in Japan

Considering Osaka meteorological bureau's nationwide disaster monitoring project with super computer " Kyo" in Kobe, we have evaluated 1sec ;σ=1cm accuracy earthquake monitoring for Kobe(Arima-Takatsuki fault), Osaka (Uemachi-active fault) and Kyoto(Hanaore-active fault), using Parameter Estimation approach; GEONAP geodetic networking, with not only 30 sec. but also 1 sec. datasets of Japan GSI's ECPs before and after 2011.3.11 East Japan earthquake. The earthquake in 2011.3.11 has still now seriously influenced social infrastructures.

2.1 Osaka-Kyoto-**30sec**-GEONAP: 2010-091, 2011-070, -080, 2014-047, 2017-055

13 Reference stations of Japan GSI's ECPs were adjusted by GEONAP, and summarised for external accuracy(discrepancies from official coordinates) and standard deviation of the unknown coordinates.

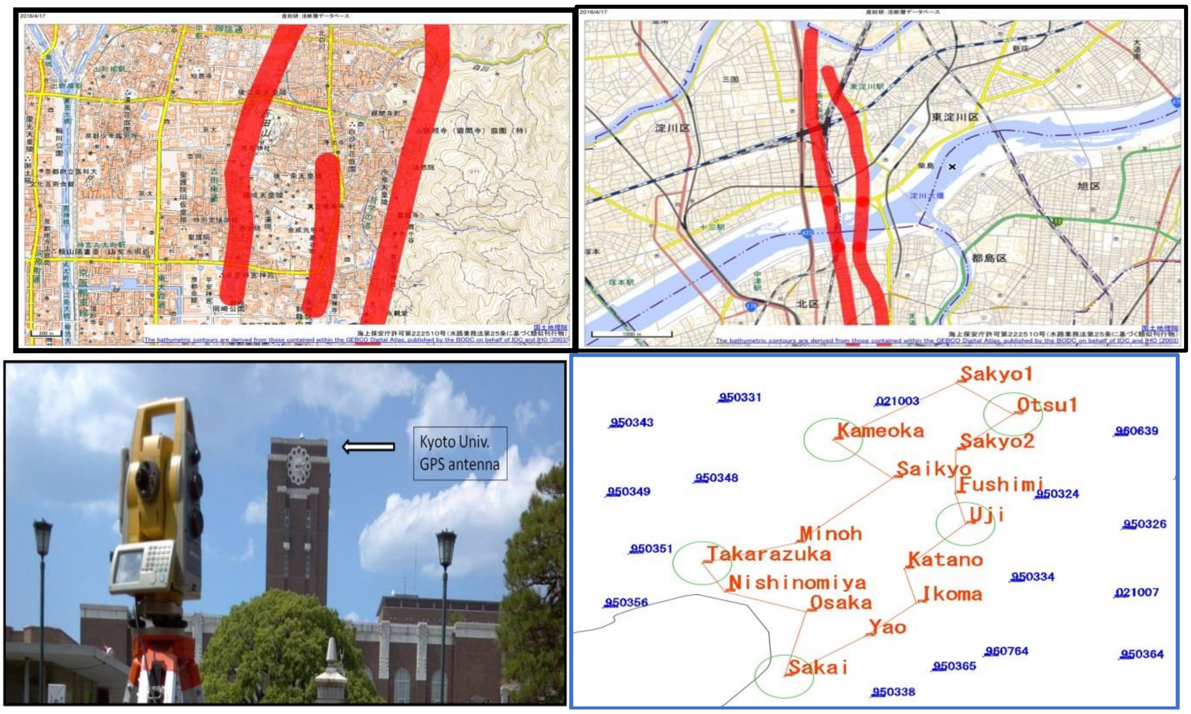


Fig.4 Kyoto (Hanaore fault) : Osaka (Uemachi fault)
Kyoto Univ. GNSS antenna and Japan GSI's ECPS (13 reference stations)

In Osaka-Kyoto active faults area, 13 ECPs have been monitored by GEONAP network adjustment, comparing with 2010 official coordinates and adjusted standard deviations at monitored 13 ECPs. The results requires consistent nationwide networking, like German DREF91 and DREF08, with respect to the accuracy. The integrated geodetic networking with levelling and gravity networking is also expected for earthquake prediction.

Table 1. Osaka-Kyoto network with 13 ECPs; 2010(091),2011(070),2011(080),2014(047) , 2017(055)

京都大阪地域15点電子基準点:測地網平均計算:実施期日(DOY)一覧表

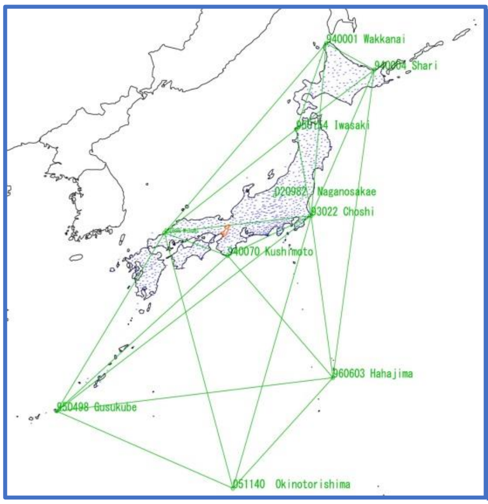
	電子基準点	西暦年	2010			2011						2011					
3		西暦月日	401			311						321					
4		DOY	91			70						80					
5		30sec/1sec	30sec														
6	点番号	名称	σXG	σYG	σZG	ΔXG	ΔYG	ΔZG	σXG	σYG	σZG	ΔXG	ΔYG	ΔZG	σXG	σYG	σZG
7	4桁	>注記	単位:m			単位:m						単位:m					
8	67	箕面	0.10	0.10	0.10	0.002	0.015	0.010	0.03	0.03	0.03	0.002	0.017	0.006	0.00	0.00	0.00
9	322	大津1	0.02	0.02	0.02	-0.014	-0.086	-0.038	0.01	0.01	0.00	-0.029	-0.081	-0.012	0.00	0.00	0.00
10	332	亀岡	0.02	0.02	0.01	-0.014	0.008	0.018	0.01	0.01	0.00	-0.016	0.010	0.016	0.00	0.00	0.00
11	333	京都西京	0.02	0.02	0.01	-0.011	0.005	0.011	0.01	0.01	0.00	-0.010	0.006	0.011	0.00	0.00	0.00
12	335	交野	0.02	0.02	0.01	0.007	0.011	0.002	0.01	0.00	0.00	0.008	0.009	-0.003	0.00	0.00	0.00
13	336	大阪	0.02	0.02	0.02	0.001	0.010	0.003	0.01	0.01	0.01	0.008	0.014	-0.003	0.00	0.00	0.00
14	337	堺	0.02	0.02	0.01	0.001	-0.058	-0.008	0.01	0.01	0.00	0.007	-0.060	-0.015	0.00	0.00	0.00
15	353	宝塚	0.02	0.02	0.01	0.001	0.017	0.001	0.01	0.00	0.00	0.003	0.017	-0.004	0.00	0.00	0.00
16	355	西宮	0.02	0.02	0.01	0.011	0.006	-0.008	0.01	0.00	0.00	0.013	0.008	-0.010	0.00	0.00	0.00
17	644	京都伏見	0.02	0.02	0.01	-0.008	0.015	0.019	0.01	0.01	0.00	-0.010	0.016	0.016	0.00	0.00	0.00
18	760	宇治	0.02	0.02	0.02	-0.004	0.015	0.011	0.01	0.01	0.00	-0.003	0.016	0.008	0.00	0.00	0.00
19	761	八尾	0.02	0.02	0.01	0.010	0.010	-0.004	0.01	0.01	0.00	0.011	0.014	-0.006	0.00	0.00	0.00
20	763	生駒	0.02	0.02	0.01	0.013	0.011	-0.001	0.01	0.01	0.00	0.014	0.013	-0.004	0.00	0.00	0.00

:地心座標最確値:標準偏差:年次別3D変位量(2010年起算)

	電子基準点	西暦年	2014						2017					
3		西暦月日	216						303					
4		DOY	47						55					
5			30sec											
6	点番号	名称	ΔXG	ΔYG	ΔZG	σXG	σYG	σZG	ΔXG	ΔYG	ΔZG	σXG	σYG	σZG
7	4桁	>注記	単位:m						単位:m					
8	67	箕面	0.011	0.017	0.004	0.01	0.01	0.01	0.012	0.010	-0.007	0.02	0.02	0.02
9	322	大津1	-0.027	-0.095	-0.017	0.00	0.00	0.00	-0.037	-0.104	-0.025	0.00	0.00	0.00
10	332	亀岡	-0.020	-0.018	0.014	0.00	0.00	0.00	-0.024	-0.028	0.010	0.00	0.00	0.00
11	333	京都西京	-0.005	0.005	0.003	0.00	0.00	0.00	-0.006	-0.002	0.005	0.00	0.00	0.00
12	335	交野	0.018	0.006	0.000	0.00	0.00	0.00	0.017	0.014	0.006	0.00	0.00	0.00
13	336	大阪	0.013	0.014	-0.007	0.00	0.00	0.00	0.026	0.026	-0.003	0.00	0.00	0.00
14	337	堺	0.010	-0.052	-0.013	0.00	0.00	0.00	0.014	-0.040	-0.004	0.00	0.00	0.00
15	353	宝塚	0.000	0.016	-0.001	0.00	0.00	0.00	-0.003	0.005	-0.007	0.00	0.00	0.00
16	355	西宮	0.007	0.009	-0.005	0.00	0.00	0.00	0.008	0.016	-0.004	0.00	0.00	0.00
17	644	京都伏見	-0.023	0.023	0.023	0.00	0.00	0.00	-0.028	0.019	0.022	0.00	0.00	0.00
18	760	宇治	-0.013	0.024	0.005	0.00	0.00	0.00	-0.013	0.020	-0.002	0.00	0.00	0.00
19	761	八尾	0.014	0.021	0.001	0.00	0.00	0.00	0.013	0.041	0.011	0.00	0.00	0.00
20	763	生駒	0.015	0.028	-0.001	0.00	0.00	0.00	0.015	0.030	-0.001	0.00	0.00	0.00

2.2 All Japan(7 Pts) - Osaka- Kyoto(13 Pts)= 20 ECPs- **30sec**-data GEONAP geodetic networking

As IGS has 500 reference stations with 30sec observable and official coordinates, we conducted 30sec-data GEONAP geodetic networking, using GPS data only as the first stage towards multi GNSS networking. Next figure and table shows the first result of simultaneous adjustment of Japan islands as a whole of 7 ECPs and in Kyoto-Osaka area of 13 ECPs with 2010-2017 datasets.



PEGASUS-NET:GEONAP測地網平均計算:日本全域+京都・大阪地域:20点 座標較差-標準偏差比較表(4/4):

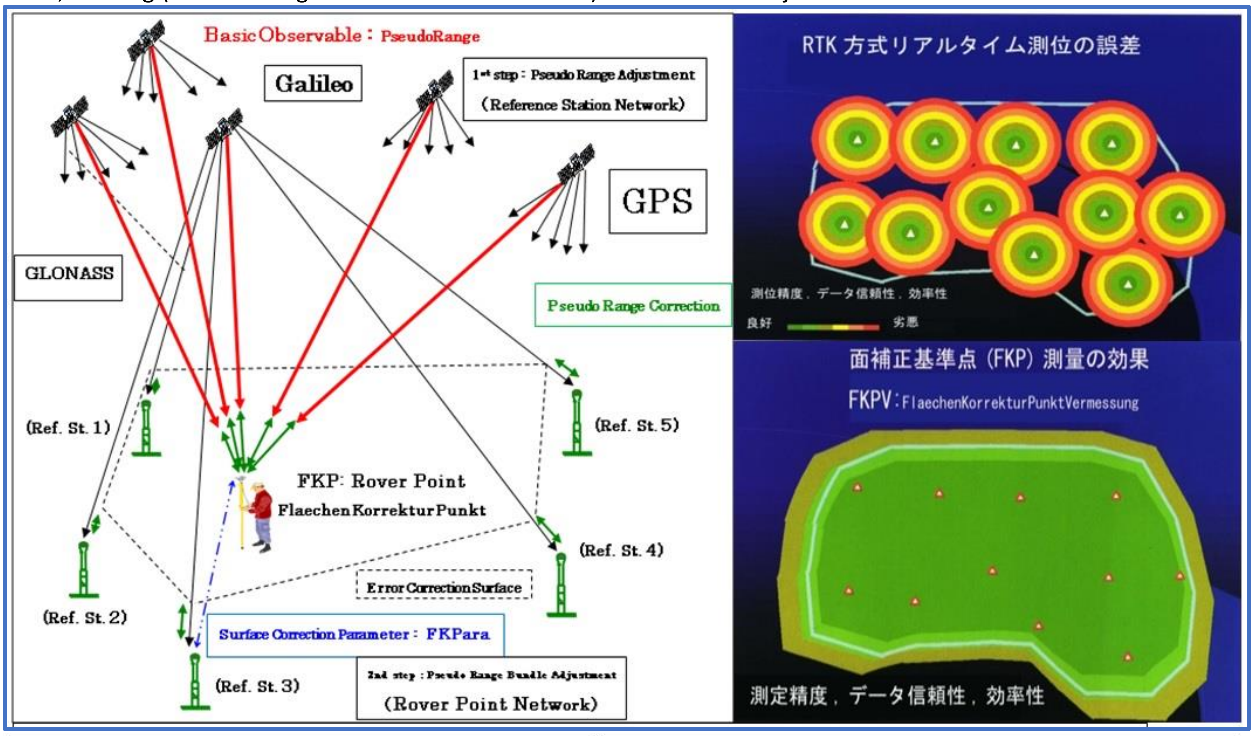
起算:2010-091					標準偏差(単位:m)			座標較差(単位:m):2010-091起算		
電子基準点		2017-055:WGS84準拠楕円体								
番号	名称	XG	YG	ZG	σXG	σYG	σZG	δXG	δYG	δZG
1	稚内	—	—	—	0.02	0.02	0.02	0.32	0.02	−1.10
4	斜里	—	—	—	0.01	0.01	0.01	0.41	−0.04	−1.03
154	岩崎	—	—	—	0.01	0.01	0.01	−0.56	−0.27	−1.06
388	三隅	—	—	—	0.02	0.02	0.02	0.01	0.09	0.16
498	城辺	—	—	—	0.04	0.04	0.03	−0.31	0.23	1.02
603	母島	—	—	—	0.04	0.04	0.02	0.10	0.01	0.46
1140	沖ノ鳥島	—	—	—	0.05	0.05	0.03	0.06	0.04	1.30
67	箕面	—	—	—	0.02	0.02	0.01	0.03	0.01	0.02
322	大津1	—	—	—	0.02	0.02	0.01	0.00	−0.09	−0.06
332	亀岡	—	—	—	0.02	0.02	0.01	0.00	−0.03	0.01
333	京都西京	—	—	—	0.02	0.02	0.01	0.02	−0.01	0.00
335	交野	—	—	—	0.02	0.02	0.01	0.03	0.01	0.03
336	大阪	—	—	—	0.02	0.02	0.01	0.04	0.03	0.04
337	堺	—	—	—	0.02	0.02	0.01	0.03	0.01	0.05
353	宝塚	—	—	—	0.02	0.02	0.01	0.01	0.01	0.03
355	西宮	—	—	—	0.02	0.02	0.01	0.02	0.02	0.04
644	京都伏見	—	—	—	0.02	0.02	0.01	−0.01	0.01	0.02
760	宇治	—	—	—	0.02	0.02	0.01	0.01	0.01	0.00
761	八尾	—	—	—	0.02	0.02	0.01	0.02	0.04	0.05
763	生駒	—	—	—	0.02	0.02	0.01	0.03	0.02	0.03

Fig.5 Nationwide 7 ECPs and Kyoto-Osaka 13 ECPs in 2017(DOY055): σ and discrepancies

This nationwide and simultaneous geodetic network adjustment promotes the forthcoming UN-GGRF initiative oriented ITRF global geodetic networking. For this purpose, we will proceed to compare world well known "Bernese" and "GEONAP" for other applications, like cadastral survey and GISe projects in Asian countries.

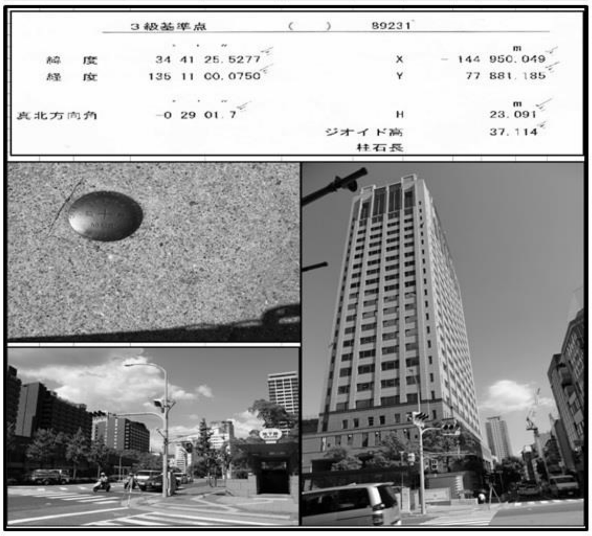
2.3 GN-SMART (PEGASUS-FKP) for 1sec 1cm real time and continuous Geodetic Network Adjustment

For Earthquake Prediction and Cadastral Reconstruction Survey based on AFIS (German cadastral survey system), real time GN-SMART was applied with Japan GSI ECPs 1sec data. 1sec 1cm accuracy Single point geodetic network adjustment for Cadastral Reconstruction Survey is now authorized by Ministry of Land, Infrastructure, Transport and Tourism: cadastral survey office as “One step parcel cadastral surveying” directly derived from ECPs reference stations. PEGASUS – FKP satellite surveying approach and effect is illustrated as follows, utilizing (Pseudo Range Error Correction Surface) based bundle adjustment.



観測地点:No9:VRS13 神戸市3級基準点 89231											
3級89231			単位:m	2012Weeks-DOY:212g		AH=1.534m		単位:mm			
A00		測点	X座標	Y座標	標高	Fix時刻	DOP	⊿x	⊿y	⊿h	衛星数
A01	26	kvrs13-1	−144950.072	77881.189	23.083	15:29:19	4.5	2	3	5	6
A01	27	kvrs13-2	−144950.065	77881.196	23.069	15:41:50	4.0	1	1	2	6
A01	28	kvrs13-3	−144950.053	77881.167	23.039	15:44:04	3.8	1	1	2	6
A01	29	kvrs13-4	−144950.067	77881.169	23.017	15:44:37	3.7	1	1	2	6
A01	30	kvrs13-5	−144950.073	77881.162	23.021	15:48:00	3.6	1	1	2	6
平均		kvrs13	−144950.065	77881.174	23.037						
標準偏差			0.008	0.015	0.024						
公式値			−144950.049	77881.185							
較差:観測値-公式値			−0.016	−0.011							

観測地点:No10:VRS12 街区多角点10A49											
街区多角10A-49			単位:m	DOY:2012-212h		AH=1.575m		単位:mm			
A00		測点	X座標	Y座標	標高	Fix時刻	DOP	⊿x	⊿y	⊿h	衛星数
A01	31	kvrs12-1	−145006.209	77765.883	23.928	16:14:44	3.3	1	1	2	6
A01	32	kvrs12-2	−145006.226	77765.886	23.921	16:17:03	3.2	1	1	1	6
A01	33	kvrs12-3	−145006.218	77765.886	23.912	16:19:04	2.7	1	1	2	7
A01	34	kvrs12-4	−145006.228	77765.875	23.888	16:21:35	2.7	1	1	2	7
A01	35	kvrs12-5	−145006.227	77765.875	23.887	16:23:35	2.7	1	1	2	7
平均		kvrs12	−145006.222	77765.881	23.907						
標準偏差			0.008	0.006	0.019						
公式値			−145006.201	77765.916							
較差:観測値-公式値			−0.021	−0.035							



街区多角点10A49成果表

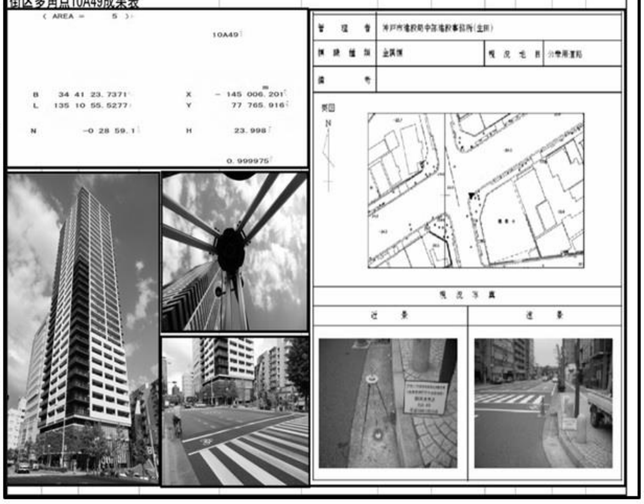
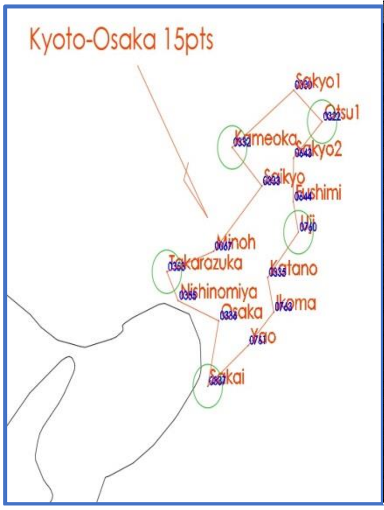


Fig.6 PEGASUS-FKP effect vs RTK solution : Kobe-FKP - VRS comparison 2018-07-31

2.4 **1sec** 1hr.-session Geodetic Network Adjustments Kyoto - Osaka – active faults area ; 2011

Kyoto-Osaka 15 ECPS -2011 DOY080-b-x-sessions out of DOY 067-070-080 are shown in the next map and a result table. New findings are enough accuracy in 1hr session and efficiency of least square adjustment vs. baseline correction in RTK according to the official surveying specification in Japan.



Electronic		Accuracy	080b		[illegible]	080b		080c … 080x1	[illegible]	080x2		080x2−080b		
Control		[illegible]			[illegible]			[illegible]	[illegible]	0.000	0.000			
Point		σ-X[m]	σ-Y[m]	σ-Z[m]	δ-X[m]	δ-Y[m]	δ-Z[m]	[illegible]	δ-X[m]	δ-Y[m]	δ-Z[m]	Δ-X[m]	Δ-Y[m]	Δ-Z[m]
ID Name	ID No.													
Ohtsu1	322	0.0008	0.0009	0.0008	-0.002	-0.011	-0.018	[illegible]	-0.001	-0.015	-0.021	0.001	-0.004	-0.003
Uji	760	0.0008	0.0009	0.0008	0.002	0.030	-0.011	[illegible]	-0.005	0.040	-0.010	-0.007	0.010	0.000
Sakai	337	0.0009	0.0009	0.0008	0.012	0.043	0.031	[illegible]	0.013	0.050	0.037	0.001	0.007	0.007
Takarazuka	353	0.0008	0.0008	0.0008	0.012	-0.031	-0.014	[illegible]	0.010	-0.031	-0.009	-0.002	0.000	0.005
Kameoka	332	0.0008	0.0009	0.0008	-0.024	-0.031	0.012	[illegible]	-0.017	-0.044	0.003	0.007	-0.013	-0.010
Sakyo1A	1170	0.0015	0.0016	0.0015	-0.012	-0.001	0.007	[illegible]	-0.011	-0.004	0.007	0.001	-0.003	0.000
Saikyo	333	0.0009	0.0009	0.0009	0.003	-0.016	0.013	[illegible]	0.001	-0.015	0.010	-0.001	0.001	-0.003
Fushimi	644	0.0010	0.0010	0.0009	-0.009	0.025	0.024	[illegible]	-0.013	0.032	0.023	-0.003	0.008	0.000
Katano	335	0.0010	0.0011	0.0010	-0.010	0.048	0.020	[illegible]	-0.010	0.049	0.018	0.000	0.000	-0.001
Ikoma	763	0.0010	0.0011	0.0010	0.050	0.019	-0.022	[illegible]	0.050	0.022	-0.022	0.000	0.003	0.000
Yao	761	0.0010	0.0011	0.0010	0.017	0.035	0.029	[illegible]	0.018	0.040	0.027	0.000	0.006	-0.002
Osaka	336	0.0011	0.0011	0.0010	0.035	0.028	0.006	[illegible]	0.024	0.034	0.012	-0.010	0.006	0.006
Nishinomiya	355	0.0009	0.0010	0.0008	0.027	-0.004	-0.020	[illegible]	0.020	0.005	-0.012	-0.008	0.009	0.008
Minoh	67	0.0009	0.0009	0.0009	-0.018	0.020	0.010	[illegible]	-0.011	0.010	0.011	0.007	-0.010	0.002
Sakyo2	643	0.0009	0.0009	0.0008	-0.009	-0.001	0.012	[illegible]	-0.007	-0.001	0.007	0.003	0.000	-0.005
Average		0.0010	0.0010	0.0009	0.005	0.010	0.005	[illegible]	0.004	0.011	0.005	-0.001	0.001	0.000
Standard Deviation		0.0002	0.0002	0.0002	0.021	0.029	0.018	[illegible]	0.018	0.030	0.018	0.005	0.007	0.005

Fig.7 1sec data-1hr session adjustment (GN-SMART post processing) for 2011 DOY080-b-x-sessions

3. σ = 1cm Helicopter photogrammetry for 3D cadastral survey with precise GNSS surveying

Being accelerated by BIM (in Japan, i-Construction) initiative of 3D modelling of city and infrastructure, precise photogrammetry by helicopter- automatic bundle triangulation and real time GNSS surveying are to be realized in Kobe university, using rigorous and sound solution of geodetic network adjustment software combined with authentic least square adjustment software. As the first stage of helicopter photogrammetry were conducted from Kobe airport, using Robinson helicopter and Japanese digital cameras, including camera calibration on Japanese typical tumulus as calibration site as follows;

Fig. 8 Flight plan/index map (GoshikiDuka tumulus/ Kobe Univ. maritime science)
: Helicopter image and Helicopter camera mounting

3.1 Flight planning and accuracy estimation for GoshikiDuka tumulus and Kobe Univ. ; Maritime science

As for accuracy estimation in flight planning, we considered the 3 major aspects of aerial photography, i.e. vibration, foreword motion blur and B/H ratio based height accuracy as follows;

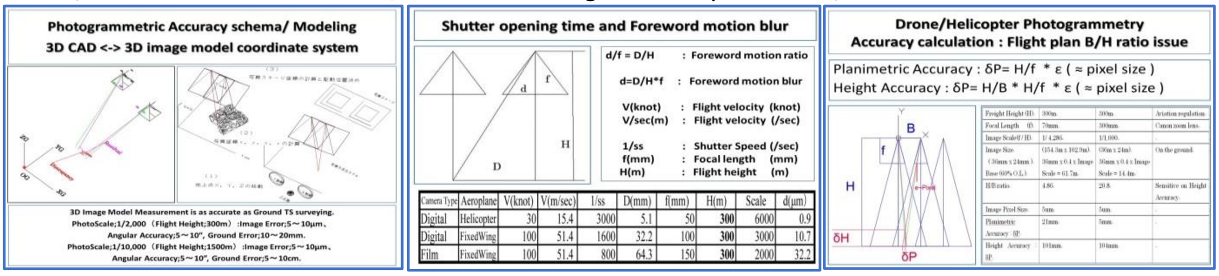


Fig.9 Photogrammetric accuracy, Foreword motion blur and Accuracy calculation

Robinson R22 － Canon EOS 5DsR 撮影画像前進ブレ量-精度計算表																					カメラ	Canon5D	単位	50Mpixels		巡航速度
五色塚古墳-神戸大学海事科学部 高精度航測法撮影計画 ジオネット株式会社 2018.11.24作成																					画素寸法	4.2	μm	地上精度		22
撮影番号	区間名	V(knot)	秒速(m)	1/ss	移動D(mm)	縮尺	地上画素(mm)	画面d(um)	f(mm)	H(m)	[illegible]	[illegible]	OL(%)	b(mm)	基線(m)	地上幅(m)	基線秒	撮像数	距離(m)	コース間隔(m)	撮影(分)	進行幅(m)	幅(m)	平面(m)	高さ(m)	km
巡1	神戸空港	40																								
往復距離	40km																									f/b
撮S1	神戸大学往	40	20.6	3000	7	5000	21	1	70	350	36	24	60	14.4	72	120	3.5	556	40,000	往路	32	180	120	0.02	0.10	4.9
撮S2	神戸大学復	45	23.2	3000	8	5000	21	2	70	350	36	24	60	14.4	72	120	3.1	500	36,000	復路	26	180	120	0.02	0.10	4.9
																	画像数	1056	76,000	距離/時間	58	時間単価	80	運航費(千円)		78

Fig. 10 GoshikiDuka tumulus area and Kobe Univ. maritime science campus area
: flight plan – exposures and flight accuracy table

Fig.11 GoshikiDuka 2019-03-13 : Stereo Matching DEM contour lines on Ortho Mosaic image map

Fig. 12 Kobe Univ. : Maritime science campus, GCP- VRS GNSS surveying

– OrthoMosaic contours and 3D-diorama

After having learned from 1995 Kobe earthquake, we have now realized 1sec. σ =1cm GNSS surveying, and are planning UN-GGRF initiative based on IGS references (500 stations). Earthquake and Tsunami prediction is now supported by parameter estimation approach in satellite geodesy. As for national land administration system, we are now cooperating with German GeoInformationsSysteme (GISe) with legal, administrative and technological systems, related with satellite geodesy and Helicopter / Satellite photogrammetry: 3D image modelling on 3D-CAD systems. Now we establish basic textbooks and practical systems, with 3D digitizers on 3D-CAD system, as our ancestor surveyors did in 1820s and 1880s, based on universal and specific theory and instruments, against the expected natural and artificial disasters, such as earthquake, tsunami, typhoon and atomic explosion.

3.2 Subjects for precise 3D Image Modelling after camera calibration

For practical and authentic Helicopter photogrammetry, we need the following subjects to be realized on helicopter and digital camera; i.e. flight – planning- controlling units and camera calibration cubic frame.

Fig. 13 Calibration Cubic and Total Station measurement : Photogrammetry - 3D Image Modelling

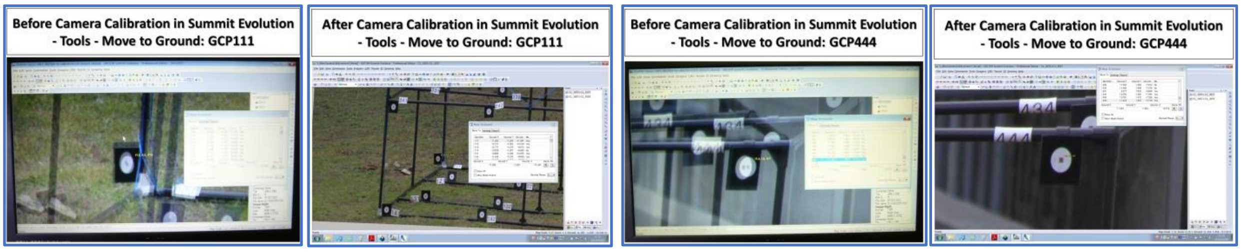


Fig. 14 GCP111 before/after camera calibration : GCP444 before/after camera calibration

Conclusion

For resilient national land administration, earthquake prediction and reconstruction of the Nankai trough area is indispensable by precise surveying approaches. UN-GGRF initiative supports nationwide, regional and local geodetic networking in GNSS surveying and helicopter photogrammetry as the most effective approaches. Based on our parameter estimation approach in geodesy, bundle adjustment based photogrammetry and rigorous least square adjustment, Japanese surveyors will contribute for concrete counter measures against natural disasters, such as earthquake, tsunami and typhoon flood, in case of serious and sudden occurrence. For these accidents, we are now well prepared with theoretical references and well proven achievements, so we could proceed to take measures and establish the state of the art technology in 4D- Image Map Archive Designed Area Studies, configuring Historical Reality from existing historical maps and aerial/ satellite images, using photogrammetry.

Acknowledgements

This research paper has been prepared and submitted for JISDM2019, supported by achievements of German authentic satellite geodesy. Authors would like to express deep gratitude to Dr. Guenter Seeber and Dr. Gerhard Wuebbena, in theoretical and practical sense. New practices will be reflected to Japanese official specifications, which would be applied to the next 10 year plan for the national land survey project nationwide.

References : all are now translated in Japanese

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