Data Processing and Analysis of the APRGP98 GPS Campaign

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1. Introduction

The Asia and Pacific Regional Geodetic Project 1998 (APRGP98) was performed during November 19-28 of 1998, in which total of 88 sites in the region were occupied with dual-frequency GPS receivers. The data set together with data of 18 IGS stations observed in the time period has been processed using the Bernese GPS software version 4.0 under a SUN ULTRA-1 workstation.

2. The APRGP98 Data Set and Coordinate Frame

Data of 88 sites for 10 days from 17 participating countries were collected in the APRGP98 campaign. In the data processing 18 IGS stations were chosen, cf. Figure 1. The observation occupations of 88 sites during November 19-28 of 1998 (DOY 323-332) are listed in Appendix 1. It is worth mentioning that 15 sites were not used in the data processing. The reason for that is briefly explained as follows:

a) Abnormal observations for site "QT01" was found where the value of a code pseudorange was frequently more than 40,000 km for the whole ten days,

b) only one-day data was available for site "URUM", and

c) There existed baseline pairs shorter than 10 km for "TKLA", "CCBS", "SMU1", "TG75", "RTSD", "PENH", "RP01", "MLAB", "TTAW", "TAWA", "MTAW", "TKUC", "T030". Bad results might be obtained if the same strategy of solving phase ambiguity is applied to long baselines and short baselines.

Data of the 18 IGS stations is available for the corresponding time period except for the data of XIAN station in DOY 328. The purpose of these IGS stations being chosen as the fiducial stations is:

- to convey coordinates from known IGS stations to the unknown sites,
- to strengthen the geometry of the network to obtain optimal solutions.

Therefore, 18 IGS stations in the region were chosen by considering the data quality as an criterion by our experience.

GPS positioning relates a datum. To obtain precise frame coordinates, data processing should be performed in a frame. Here the ITRF frame was chosen, which is also an resolution passed in Beijing PCGIAP meeting in 1999. For APRGP98 campaign ITRF96 coordinate frame were used during data processing, and ITRF coordinates as well as velocities of the 18 IGS stations at Epoch 1997.0 are listed in Appendix 2. These coordinates are transferred into Epoch 1998.897 corresponding to the middle of APRGP98 campaign period, cf. Appendix 3.

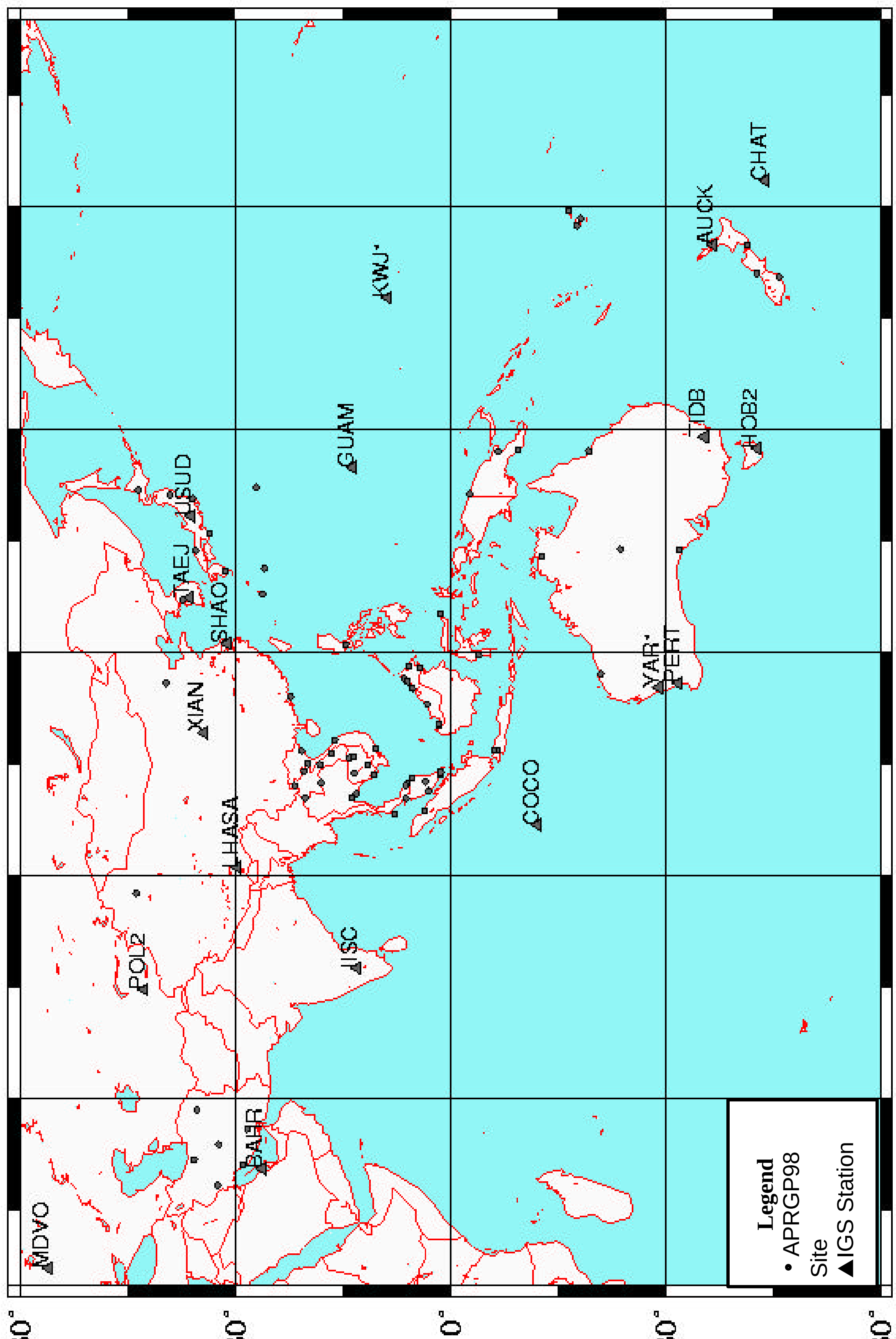


Figure 1. Distribution of APRGP98 Sites and IGS Stations Used in Data Processing

3. Processing Diagram, Model and Parameters

3.1 ***Processing Diagram***

Bernese GPS software version 4.0 was released by the Center for Orbit Determination in Europe (CODE) in 1996. The Bernese GPS software was developed as a tool for highest accuracy requirements. The functional flow diagram for data processing can be shown in Figure 2. Descriptions of each module together with the strategies applied in data processing are given as follows.

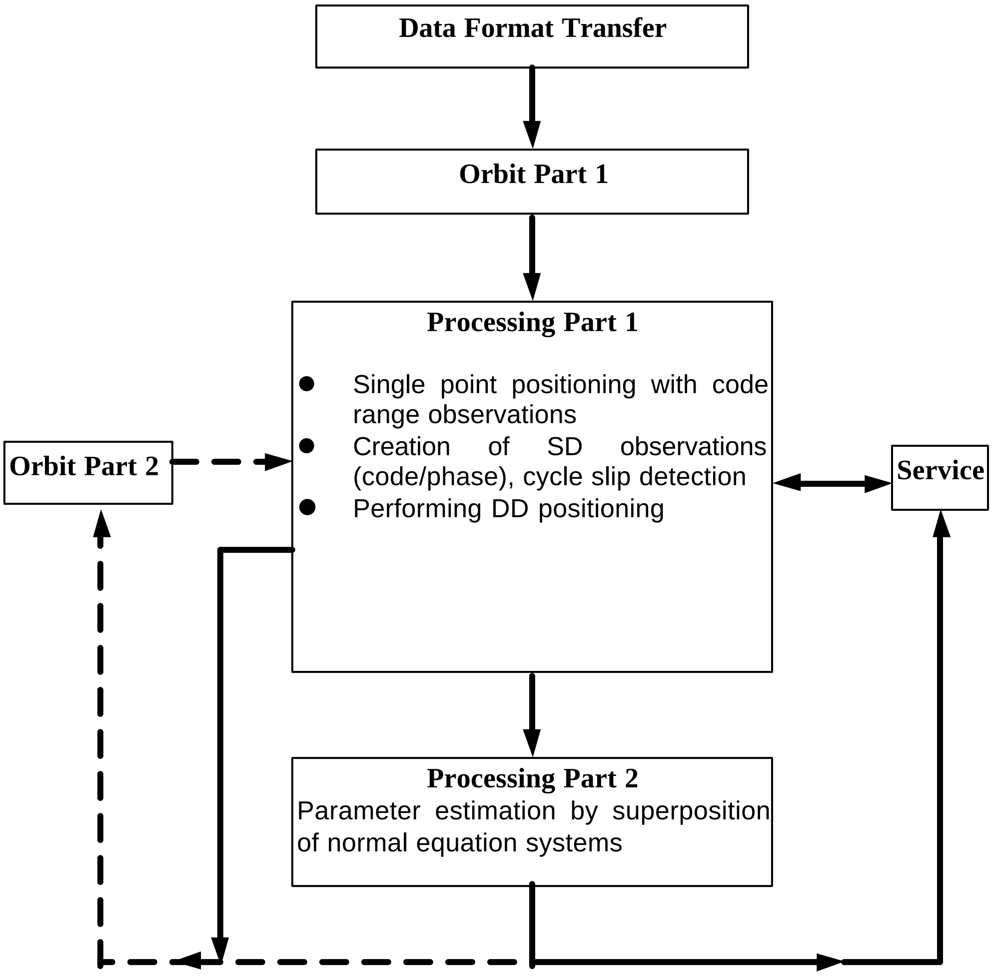


Figure 2. Flow Diagram of GPS Data Processing

The module **Data Format Transfer** generates GPS data in Bernese version 4.0 format from RINEX data format (observations, broadcast information, meteorology) for all subsequent computations.

The module **Orbit Part 1** generates source independent orbits, namely tabular orbits. Standard orbits are then generated using broadcast ephemeris/precise ephemeris.

The module **Processing Part 1** is one of two key modules in Bernese GPS software. The first function of the module is to perform single point positioning (SPP) with code ranges. An approximate position and receiver clock offset of each site are calculated as a result, where the satellite clock offset extracted from broadcast ephemeris is applied. The second function of the module is to perform parameter estimations using phase and/or code difference observations. In the sequel, the coordinates of SPP solution are then improved. Therefore, this step is not always necessary if it has already been done with data in the previous days for unknown sites. Attention should be paid to the principle of forming single-difference (SD) observations. In the process we observed the principle "maxium observations" to strengthen the geometry of the network. Obviously, this principle is an equivalance of the principle "shortest baseline" in most cases since the nearest sites are most likely simutaneously observed. In double-difference (DD) data processing issue of phase ambiguity resolution should be solved well to obtain reliable results.

The module **Processing Part 2** deals mainly with normal equation systems. The baseline solution and related covariance matrix can be overlaid. In the process information such as ambiguity and troposphere parameters, can be removed from the normal equation systems for large network, or number of troposphere parameters (per station and per day) can be changed. Constrains of coordinates of IGS stations can be applied in this step.

The module **Orbit Part 2** interacts with **Processing Part 2** to deal with precise orbit, i.e. we may add stochastic orbit parameters to relax the orbit. In our case, however, we did not relax the orbit. Instead, we fixed the orbit generated from IGS precise ephemeris. The reason is based on the fact that the IGS precise ephemeris are calculated with permannent stations which are globally well-distributed. Compared with global permanent stations in orbit determination the 88 stations in APRGP98 campaign is not good enough in both number and geographical distribution. On the other hand, the current accuracy of the IGS precise ephemeris is better than 10 cm which may lead to maximux baseline error of 1-4 mm for baselines of 3500 km, cf. Jiang et al. (1998). Note that a baseline is shorter than 3500 km in most cases when observing our principle in forming SD observations.

3.2 Model and Parameters

- IGS precise ephemeris were adopted,
- "least-squares search" technique was used for baselines shorter than 100 km and ionosphere-free combination (Lc) solutions were finally chosen for longer baseline, cf. Rothacher and Mervart (1996), p210,
- The trophsphere effect on positioning may change about 20 mm in 4 hours, cf. Wang (1999), and therefore this effect must be taken into consideration. Here one troposphere parameter was introduced per station and per 4 hours, and
- the cut-off angle is set to 15 degrees.

Due to the limitation of the memory capacity of the workstation used, we divided the whole network into five groups by considering the geographical distribution of the APRGP98 GPS sites, cf. Appendix 1. The neighboring two groups were connected with at least five IGS stations (cf. Appendix 3) and some APRGP98 sites (cf. Appendix 1).

4. Solutions and Analysis

Solutions of the whole network were obtained with three schemes. The first one was the so-called fixed solution in which the 18 IGS stations were fixed to their known positions, the second one was the free solution in which the 18 IGS stations were used only for defining the center of the network, and the last solution was the constrained solution in which the 18 IGS stations were constrained with the a priori sigma released by IGS.

4.1 Repeatability for Daily Solution

Repeatability of Coordinate Component for Daily Solution

The positioning accuracy can be shown with the repeatability of the coordinate component for daily solution as the repeatability of the coordinate component can be considered as an external criterion of the positioning accuracy. Figure 3 shows the repeatability of the coordinate component of each APRGP98 sites for the three schemes.

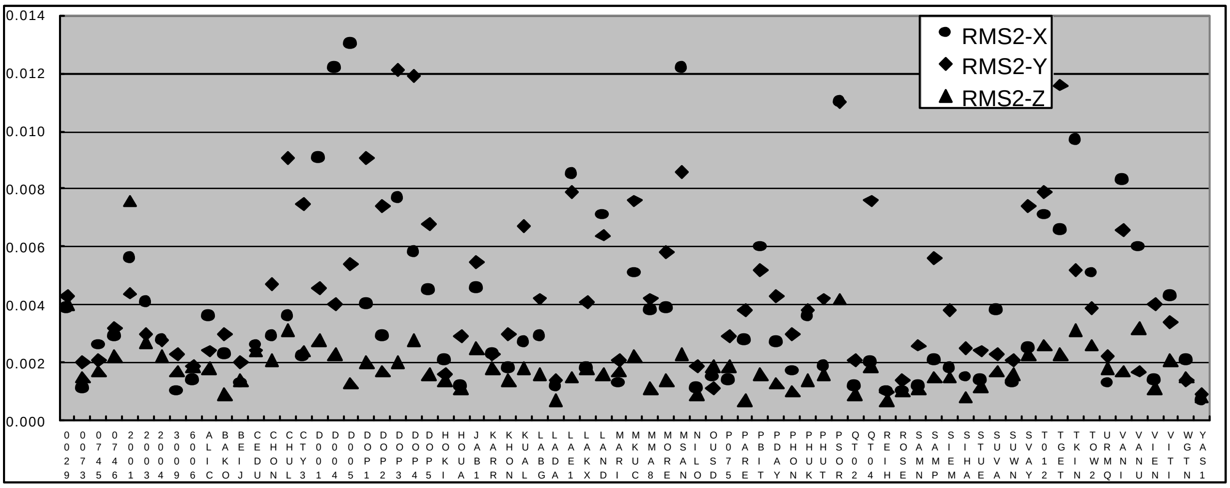
It can be shown from Figure 3 that, for fixed solution and free solution the repeatability of the three componets is better than 10 mm for more than 90 percent of the sites. The average repeatability is shown in Table 1. With respect to scheme 1 and scheme 2, there are seven sites with the repeatability of the three components over 10 mm: “MSAN”, “TGET”, “D004”, “D005”, “DOP3”, “DOP4”, “PSOR”; with respect to the constrained solution, the repeatability is a bit worse.

Table 1. Average Repeatability of the Coordinate Component

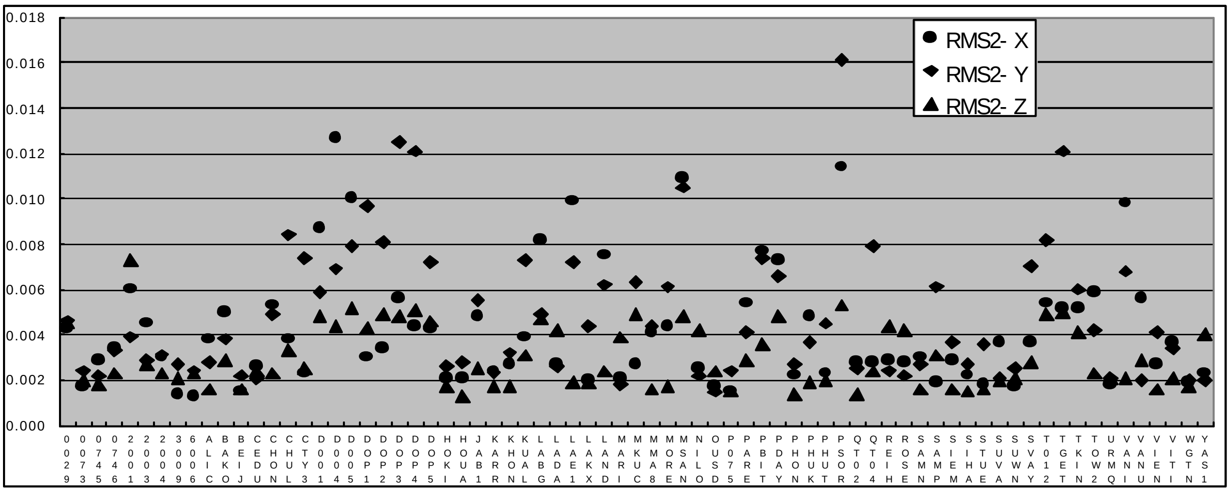
Scheme	X (mm)	Y (mm)	Z (mm)
fixed solution	3.7	4.4	1.9
free solution	4.2	4.9	3.0
Constrained solution	6.8	6.1	7.5

Repeatability of Baseline for Daily Solution

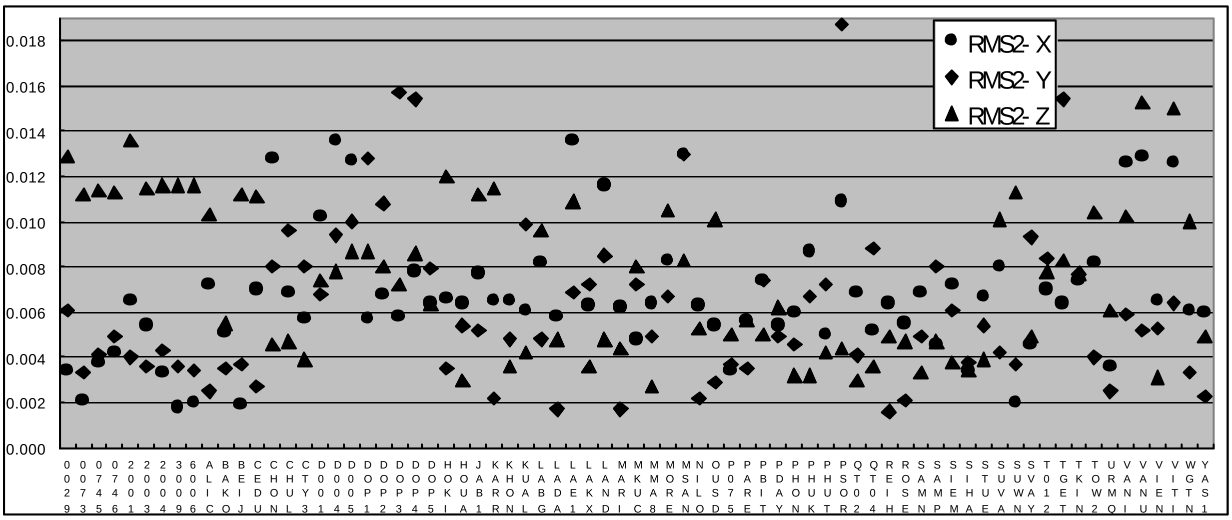
In addition to the analysis of the repeatability of the coordinate component, the repeatability of baseline is also of significance as a measure of the quality of final



Fixed solution



Free solution



Constrained solution

Figure 3. Repeatability of Coordinate Components of APRGP'98 Sites

results. Table 2 lists the repeatability of baseline for daily solution for the five groups (cf. Section 3 of the paper) including the constant error (δ) and scale error (σ). One can see from Table 2 that the repeatability of baseline is at a level of 10^{-9}, which shows the reliability of each daily solution.

Table 2. Repeatability of Baseline for Daily Solution, in mm

	δ (mm)	σ (10^{-9})	Baseline (10^{-9})
Group 1	0.2	2.4	2.6
Group 2	0.6	4.1	4.0
Group 3	0.4	4.4	5.6
Group 4	5.6	1.4	3.4
Group 5	5.5	2.7	7.7

4.2 Final Results

The final solutions for the three schemes were obtained. Positioning accuracy in north-south, west-ease and up components for the three schemes is shown Table 3.

Table 3. Final Positioning Accuracy of the Coordinate Component

Scheme	N (mm)	E (mm)	U (mm)
fixed solution	2.9	7.6	13.9
free solution	4.4	9.4	12.6
Constrained solution	21.9	16.5	19.8

One can see from Table 3 that the fixed solution gives the best solution and the free solution gives a similar result. Horizontal positioning accuracy for both solutions are at millimeter level. This indicates that the coordinates of the IGS stations used are reliable which in turn takes the role in strengthening the whole network. On the other hand, the constrained solution is not as good as the first two solutions. The reason can be explained as the fact that the constrained condition is not properly set with the a priori sigma for each IGS station, cf. Appendix 2. Above all, the fixed solution was finally selected. The coordinate components together with the RMS values for each site are listed in Appendix 4.

5. Summary and Recommendation

The APRGP98 GPS data was processed with the Bernese GPS software. Data from 18 IGS stations was used. Solutions with three schemes were obtained. The fixed solution is the best one. The repeatability of the three coordinate components is 3.7 mm, 4.4 mm and 1.9 mm respectively. The repeatability of baseline for daily solution is at a level of 10^{-9}. The horizontal accuracy is about 2.9 mm and 7.6 mm for north-south and east-west components and 13.9 mm for up component.

In the data processing some problems occurred. In some area the GPS sites are distributed densely. Some baselines are even several kilometers long. In our opinion, this is of no significance in establishing a regional geodetic network. Attention should also be paid to the observation files. Parameters, such as antenna type, antenna height, site name and file name, were not given correctly in some data files which might lead to difficulty in the data processing. Since the regional campaign will continue in this year, we recommend that each observation file in RINEX format be standardized.

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Appendix 1. Observation Data of APRGP98 and Site Grouping

(blank: data available, X: data not available)

No.	Site	323	324	325	326	327	328	329	330	331	332	Group
1	0029	X							X			2
2	0073											2
3	0745											2
4	0746											2
5	2001											2
6	2003											2
7	2004											2
8	3009											2
9	6006											2
10	ALIC											4
11	BAKO											5,4
12	BEIJ											2
13*	CCBS											
14	CEDU									X		4
15	CHON						X	X	X	X	X	3
16	CHUL											3
17	CTY3											3
18	D001						X	X	X	X	X	5
19	D004						X	X	X	X	X	5
20	D005						X	X	X	X	X	5
21	DOP1						X	X	X	X	X	5
22	DOP2						X	X	X	X	X	5
23	DOP3						X	X	X	X	X	5
24	DOP4						X	X	X	X	X	5
25	DOP5						X	X	X	X	X	5
26	HOKI											4
27	HOUA											3
28	JAB1	X										4
29	KARR									X		4
30	KHON											3
31	KUAL											5
32	LABG											4
33	LADA											1
34	LAE1	X										4
35	LAKX											3
36	LAND	X	X					X	X	X	X	3
37	MARI											1
38	MKUC						X	X	X	X	X	5
39*	MLAB						X	X	X	X	X	
40	MMA8							X				3
41	MORE											4
42	MSAN						X	X	X	X	X	5
43*	MTAW						X	X	X	X	X	
44	NILO											1
45	OUSD											4

Appendix 1. continued

No.	Site	323	324	325	326	327	328	329	330	331	332	Group
46	P075											2,3
47	PARE											5,4
48	PBIT	X	X	X	X							5,4
49	PDAY	X	X	X	X							5,4
50*	PENH			X	X	X	X					
51	PHON											3
52	PHUK						X	X	X	X	X	3
53	PHUT			X								3
54	PSOR	X	X	X	X	X	X					5
55*	QT01											
56	QT02											3
57	QT04						X					3,5
58	REIH											1
59	ROSE											1
60*	RP01						X	X	X	X	X	
61*	RTSD											
62	SAMN											3
63	SAMP											5
64	SIEM	X										3
65	SIHA	X	X	X								3
66*	SMU1											
67	STUE	X	X									3
68	SUVA											4
69	SUWN											2
70	SVAY	X	X	X	X	X	X					3,5
71	T012						X	X	X	X	X	5
72*	T030						X	X	X	X	X	
73*	TAWA											
74*	TG75			X	X						X	
75	TGET					X	X	X	X	X	X	5
76	TKIN						X	X	X	X	X	5
77*	TKLA						X	X	X	X	X	
78*	TKUC						X	X	X	X	X	
79	TOW2											4
80*	TTAW						X	X	X	X	X	
81	URMQ											1,2
82	VANI											4
83	VANU	X	X						X	X	X	4
84	VIEN											3
85	VITI	X	X						X	X	X	4
86	WGTN											4
87	YAS1											1
88*	URUM	X	X	X	X	X	X	X	X		X	

* Not used in data processing

Appendix 2. ITRF96 Coordinates at Epoch 1997.0 and Velocities

Station	X/Vx	Y/Vy	Z/Vz	Sigma		
AUCK	-5105681.020	461564.046	-3782181.767	.004	.004	.004
	-.0247	-.0194	.0320	.0013	.0024	.0014
BAHR	3633909.068	4425275.486	2799861.265	.004	.004	.004
	-.0307	.0091	.0301	.0045	.0038	.0032
CHAT	-4590670.919	-275483.000	-4404596.788	.004	.004	.004
	-.0240	.0138	.0247	.0012	.0016	.0012
COCO	-741950.004	6190961.634	-1337768.594	.005	.005	.004
	-.0423	.0084	.0544	.0019	.0010	.0018
GUAM	-5071312.795	3568363.498	1488904.313	.004	.003	.004
	.0066	.0068	.0042	.0017	.0019	.0011
HOB2	-3950071.365	2522415.187	-4311638.367	.004	.004	.004
	-.0409	.0048	.0419	.0018	.0013	.0018
IISC	1337937.273	6070315.394	1427876.248	.056	.112	.037
	-.0392	.0020	.0358	.0039	.0012	.0020
KWJ1	-6160881.011	1339882.965	960810.459	.004	.004	.003
	.0241	.0694	.0303	.0010	.0017	.0015
LHAS	-106937.663	5549269.597	3139215.753	.004	.004	.004
	-.0443	-.0078	.0160	.0027	.0013	.0013
MDVO	2844672.178	2161066.452	5266365.656	.016	.013	.028
	-.0240	.0089	.0086	.0014	.0013	.0009
PERT	-2368686.972	4881316.520	-3341796.170	.003	.004	.004
	-.0514	.0075	.0476	.0020	.0032	.0023
POL2	1239971.593	4530790.063	4302578.765	.004	.004	.004
	-.0290	.0056	.0039	.0036	.0018	.0017
SHAO	-2831733.262	4675666.046	3275369.515	.004	.004	.004
	-.0309	-.0117	-.0120	.0019	.0025	.0019
TAEJ	-3120422.917	4086355.453	3761769.614	.012	.015	.014
	-.0292	-.0109	-.0125	.0023	.0020	.0019
TIDB	-4460996.134	2682557.080	-3674443.702	.004	.003	.004
	-.0368	-.0045	.0479	.0011	.0008	.0010
USUD	-3855262.992	3427432.525	3741020.358	.003	.003	.003
	-.0052	.0011	-.0052	.0009	.0010	.0008
XIAN	-1735212.500	4976840.116	3580538.361	.005	.010	.008
	-.0248	-.0011	-.0097	.0009	.0009	.0013
YAR1	-2389025.539	5043316.874	-3078530.738	.003	.003	.004
	-.0498	.0056	.0491	.0003	.0005	.0005

Appendix 3. ITRF96 Coordinates at Epoch 1998.897, Velocities and Station Grouping in Data Processing

Station	X	Y	Z	Group
AUCK	-5105681.067	461564.009	-3782181.706	4
BAHR	3633909.010	4425275.503	2799861.322	1
CHAT	-4590670.965	-275482.974	-4404596.741	4
COCO	-741950.084	6190961.650	-1337768.491	3,5,4
GUAM	-5071312.782	3568363.511	1488904.321	3,5,4
HOB2	-3950071.443	2522415.196	-4311638.288	4
IISC	1337936.756	6070317.172	1427876.586	1,2,3,5
KWJ1	-6160880.965	1339883.097	960810.516	4
LHAS	-106937.747	5549269.582	3139215.783	1,2,3,5
MDVO	2844672.240	2161070.113	5266363.830	1
PERT	-2368687.070	4881316.534	-3341796.080	4
POL2	1239971.538	4530790.074	4302578.772	1,2
SHAO	-2831733.321	4675666.024	3275369.492	2,3,5
TAEJ	-3120422.972	4086355.432	3761769.590	2,
TIDB	-4460996.224	2682557.084	-3674443.629	4
USUD	-3855263.002	3427432.527	3741020.348	2
XIAN	-1735212.547	4976840.114	3580538.343	2,3,5
YAR1	-2389025.633	5043316.885	-3078530.645	4

Appendix 4. Fixed Solution for APRGP98 GPS Campaign

Site	X (M)	RMS	Y (M)	RMS	Z (M)	RMS
CHON	-1190208.2879	0.0003	6097682.8124	0.0005	1438406.3389	0.0001
CHUL	-1132728.3295	0.0003	6092488.4150	0.0006	1504562.0686	0.0002
PHUK	-912741.9024	0.0003	6253870.4375	0.0005	855385.4223	0.0001
VIEN	-1314797.6255	0.0002	5923043.6541	0.0004	1961129.5838	0.0001
COCO	-741950.0840	0.0000	6190961.6499	0.0000	-1337768.4913	0.0000
CTY3	-1916791.0355	0.0002	5822975.0647	0.0004	1754668.8230	0.0001
P075	-2408855.2545	0.0002	5391043.2358	0.0003	2403591.1273	0.0001
GUAM	-5071312.7820	0.0000	3568363.5110	0.0000	1488904.3211	0.0000
MMA8	-3177117.9797	0.0004	5293321.2205	0.0005	1597133.0028	0.0002
HOUA	-1084448.8588	0.0002	5887162.3003	0.0004	2195043.0032	0.0002
PHON	-1243325.3262	0.0002	5798971.2722	0.0003	2342488.9178	0.0002
IISC	1337936.7330	0.0003	6070317.1232	0.0005	1427876.5797	0.0001
KHON	-1689963.9217	0.0002	5951481.6789	0.0004	1545756.3293	0.0001
LAKX	-1567312.5760	0.0002	5855889.6404	0.0004	1978061.4576	0.0001
PHUT	-1736467.2984	0.0003	5861984.6653	0.0005	1812076.4254	0.0002
QT04	-1843711.9005	0.0002	5998027.7019	0.0004	1138672.7757	0.0001
LHASA	-106937.7470	0.0000	5549269.5821	0.0000	3139215.7828	0.0000
SAMN	-1451207.6140	0.0002	5801838.0269	0.0004	2211983.0410	0.0002
QT02	-1724394.3163	0.0002	5714553.8037	0.0004	2239923.5901	0.0002
SHAO	-2831733.3209	0.0000	4675666.0240	0.0000	3275369.4921	0.0000
XIAN	-1735212.5471	0.0000	4976840.1140	0.0000	3580538.3430	0.0000
SIEM	-1481813.4515	0.0002	6025851.6720	0.0004	1469486.6594	0.0001
STUE	-1706562.2268	0.0002	5962886.4475	0.0004	1482541.1888	0.0001
LAND	-1608477.0427	0.0004	6039324.2279	0.0008	1268553.7029	0.0002
SIHA	-1466153.4744	0.0002	6095949.2470	0.0004	1166708.1519	0.0001
SVAY	-1703382.0078	0.0003	6023545.6705	0.0006	1218999.5191	0.0002
ALIC	-4052051.9160	0.0004	4212836.0847	0.0004	-2545105.7393	0.0002
CEDU	-3753472.3317	0.0002	3912740.9914	0.0002	-3347960.7806	0.0002
AUCK	-5105681.0670	0.0000	461564.0090	0.0000	-3782181.7059	0.0000
HOKI	-4635696.9927	0.0003	735523.1570	0.0002	-4304158.6575	0.0003
BAKO	-1836969.0014	0.0002	6065617.1771	0.0003	-716257.7897	0.0001
LABG	-1836967.2883	0.0002	6065621.7126	0.0004	-716219.2769	0.0001
PARE	-3147782.6516	0.0002	5529856.7807	0.0003	-439535.5542	0.0001
YAR1	-2389025.6330	0.0000	5043316.8850	0.0000	-3078530.6450	0.0000
HOB2	-3950071.4429	0.0000	2522415.1958	0.0000	-4311638.2882	0.0000
TOW2	-5054582.7828	0.0003	3275504.4145	0.0002	-2091539.6090	0.0001
CHAT	-4590670.9651	0.0000	-275482.9738	0.0000	-4404596.7409	0.0000
WGTN	-4777269.3874	0.0002	434270.0176	0.0001	-4189484.5852	0.0002
KWJ1	-6160880.9650	0.0000	1339883.0970	0.0000	960810.5160	0.0000
VANI	-4972631.2048	0.0004	3983209.0186	0.0003	-296767.0667	0.0001
OUSD	-4387888.5808	0.0002	733420.9241	0.0001	-4555178.5295	0.0002
SUVA	-6060677.1471	0.0004	166617.3194	0.0002	-1973761.6492	0.0002
TIDB	-4460996.2240	0.0000	2682557.0839	0.0000	-3674443.6290	0.0000
KARR	-2713832.3524	0.0003	5303935.0938	0.0004	-2269514.9140	0.0002
MORE	-5288524.5975	0.0004	3409956.1444	0.0003	-1038575.0884	0.0001
PERT	-2368687.0700	0.0000	4881316.5341	0.0000	-3341796.0799	0.0000
LAE1	-5312857.0596	0.0004	3451108.0253	0.0003	-736322.8034	0.0001
JAB1	-4236442.8871	0.0004	4559929.5878	0.0004	-1388624.5372	0.0001
VANU	-6119100.9415	0.0006	62728.2989	0.0002	-1792699.8555	0.0002
VITI	-6073527.6418	0.0006	276502.0183	0.0002	-1921630.3030	0.0002
PDAY	-1841390.6945	0.0004	6069118.9518	0.0007	-672984.8736	0.0001

PBIT	-3674851.3029	0.0004	5210705.1135	0.0005	159398.6926	0.0001
MKUC	-2200986.1321	0.0008	5983687.1658	0.0011	180479.6951	0.0001
DOP2	-1500246.2400	0.0005	6197397.9620	0.0008	152195.8709	0.0001
D001	-2702793.0747	0.0008	5747549.4169	0.0011	583412.7021	0.0002
D005	-2827033.5666	0.0009	5673602.9560	0.0012	705604.6342	0.0002
T012	-2496815.4968	0.0008	5858477.2661	0.0011	355737.7206	0.0001
D004	-2984273.5864	0.0000	5617687.2733	0.0009	469697.2202	0.0001
MSAN	-2990750.4103	0.0007	5596338.0737	0.0009	644936.6637	0.0002
SAMP	-964465.0202	0.0003	6291997.2616	0.0006	400195.9001	0.0001
KUAL	-1443668.1924	0.0003	6184650.1765	0.0005	587309.9703	0.0001
TKIN	-2790190.3431	0.0008	5697101.1457	0.0011	660474.5601	0.0002
DOP1	-1263943.4534	0.0005	6242702.9839	0.0008	334310.4603	0.0001
DOP3	-1391259.0570	0.0005	6212965.5005	0.0008	382801.3444	0.0001
DOP5	-1143197.9760	0.0007	6237895.1618	0.0011	677621.3191	0.0002
DOP4	-1353514.1772	0.0007	6196995.5177	0.0012	666525.0051	0.0002
TGET	-1329733.1018	0.0010	6199766.6467	0.0016	687129.5700	0.0002
PSOR	-4204738.1912	0.0014	4795031.9603	0.0015	-97013.0523	0.0002
2001	-3642148.5157	0.0003	2861482.2221	0.0003	4370365.6089	0.0004
3009	-3997615.4618	0.0003	3276762.6968	0.0003	3724230.5711	0.0003
2003	-4488925.8175	0.0004	3483902.9132	0.0004	2887743.1762	0.0003
2004	-3565271.2914	0.0003	4118973.2260	0.0004	3306293.3779	0.0003
TAEJ	-3120422.9719	0.0000	4086355.4320	0.0000	3761769.5901	0.0000
6006	-3822373.3716	0.0003	3699359.8949	0.0003	3507585.8196	0.0003
0745	-3512919.5187	0.0004	4524558.3094	0.0004	2795882.5381	0.0003
0746	-3786805.6361	0.0004	4311845.9204	0.0004	2774485.2065	0.0003
0073	-3591893.3747	0.0003	3758832.9318	0.0003	3682342.8478	0.0003
BEIJ	-2148743.8820	0.0002	4426641.3048	0.0004	4044655.9441	0.0003
URMQ	193030.8227	0.0001	4606851.3362	0.0002	4393311.4277	0.0002
POL 2	1239971.5380	0.0000	4530790.0740	0.0000	4302578.7721	0.0000
SUWN	-3062022.7003	0.0003	4055448.0804	0.0003	3841818.3179	0.0003
USUD	-3855263.0020	0.0000	3427432.5270	0.0000	3741020.3480	0.0000
BAHR	3633909.0100	0.0000	4425275.5030	0.0000	2799861.3220	0.0000
LADA	3151871.9095	0.0002	4654363.3494	0.0003	3005669.3096	0.0002
MDVO	2844672.2400	0.0000	2161070.1130	0.0000	5266363.8300	0.0000
NILO	3582731.9643	0.0003	4026235.5145	0.0003	3399695.7188	0.0002
REIH	3509963.7409	0.0003	4347105.4927	0.0003	3066072.1964	0.0002
ROSE	3185578.8594	0.0002	4356094.3711	0.0003	3390474.9506	0.0002
YAS 1	2726445.1205	0.0003	4442816.4871	0.0003	3665092.3315	0.0002
MARI	3205584.5118	0.0002	4075347.1018	0.0003	3705004.7670	0.0002
0029	-3862395.5083	0.0004	3105010.5346	0.0004	4001962.4060	0.0004

GPS DATA ANALYSIS FOR APRG97 AND APRG98 CAMPAIGNS

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ABSTRACT

The GPS data of APRG97 and APRG98 has been analysed using GIPSY software developed in JPL. An algorithm of modified non-fiducial was adopted so as to obtain more accuracy result. The method of precise point positioning recommended by JPL was used so as to save computing time. The accuracy of the daily solutions for most site coordinates is about 1-2mm for the north component, 2-3mm for the east component and 5-10mm for the vertical component respectively. The velocities of 52 sites of which the data were repeatedly treated during this GPS data analysis have also been determined preliminary.

1. ANALYSIS PROGRAM

Asian and the Pacific Regional Geodetic Project has carried out two campaigns of simultaneous observations with GPS, SLR, VLBI, DORIS and PRARE permanent geodetic stations during Oct. 1997 and Nov. 1998, named APRG97 and APRG98 respectively. The APRG97 GPS network and APRG98 GPS network consist of 33 sites for APRG97 and about 80 sites for APRG98 respectively located in CHINA, CHINA TAIWAN, KOREA JAPAN, AUSTRALIA, INDONESIA, MALAYSIAA, PAPUA NEW GUINEA, VIETNAM, PHILIPPINES and IRAN. Recently we treated these APRG97 and APRG98 GPS data using GIPSY software developed by JPL.

The procedure of the data processing for daily coordinate solutions is summarized as follows:

Software used: GIPSY

Measurement Models:

Basic Observations: L1,L2 Two frequency Carrier phases, P code pseudo-range Used for detecting and correcting cycle slips, ambiguity estimation

Elevation angle cutoff: 15 degrees

Sampling interval: 300 second

Weighting: Uniform

Modeled Observation undifference, ionosphere-free linear combination

Troposphere: a priori Saastamoinen atmospheric correction

Tidal displacements: Solid earth tidal displacement : IERS standard(1995)

Ocean loading: IERS standard (1995)

Atmospheric load and polar tidal: not applied

Satellite Orbits: JPL orbits (from *_nf.eci files)

EOP: JPL EOP (from *tpeo_nf.nml file)

Satellite Clocks Information: JPL GPS satellite clock information (from *_nf.tdpc file)

Estimated Parameters:

Station coordinate:	modified non-fiducial, all stations, including IGS sites, are estimated in the same apriori constrain about 10 km.
Troposphere:	Zenith delay updated every epoch
Ambiguity:	estimated as real values without apriori Station clock
Corrective parameter:	estimated every step for each site

Notes:

1) In order to have a consistent reference frame so as to compare the results obtained from APRG97's GPS data and APRG98's GPS data, not only the GPS data coming from APRG97 GPS network and APRG98 GPS network, but also other GPS data coming from about 30 to 50 igs sites have been treated at the same time under the frame of ITRF97.

2) In order to avoid the twisting of the network formed by APRG's GPS sites during calculating process, a method called non-fiducial which is modified by us was adopted when these GPS data were treated. It consists of two steps.

a) All stations including IGS sites are fully relaxed and given same weight during estimating the site coordinate. In our calculating, the uncertainty of site coordinate for each station given by us is 10 km . There is no station fixed. But we fixed the GPS satellite orbits and used the GPS satellite clock information which are all come from JPL.

b) To do seven parameter transformation :

Firstly, To obtain the transformation seven parameters making use of at least 3 IGS stations by means of following equation :

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} + \begin{pmatrix} dx \\ dy \\ dz \end{pmatrix} + \begin{pmatrix} D & -r_3 & r_2 \\ r_3 & D & -r_1 \\ -r^2 & r_1 & D \end{pmatrix} \cdot \begin{pmatrix} x' \\ y' \\ z' \end{pmatrix}$$

here, x,y,z are the coordinates of IGS sites in some frame at a specified epoch . The frame we adopted was ITRF97, and the

epochs were those of observing time for APRG97 and APRG98. And the x', y', z' are the coordinates of these igs station in daily solution. The dx, dy, dz are displacement parameters, the D is the scale factor, the r1, r2 and r3 are the rotation parameters. These igs stations are called transformation fiducial stations. So the method of non-fiducial we adopted, in fact, still makes us of some sites as fiducial.

Secondly, to translate all coordinates of other sites to the frame of ITRF97 by means of the transformation seven parameters that have been obtained. In table 11, we give a transformation example of the coordinates obtained from the solution on the day 20 Nov. 1998 to the coortinates in ITRF97.

Table 1.1 : A transformation example of coordinates obtained from the solution on the day 20 Nov. 1998 to the coordinates in ITRF97

site		coordinates in ITRF97 at 1998.8	coordinates from solution	coordinates after trans-formation	residual
AREQ	x	1942826.7581	1942826.9779	1942826.7699	0.0118
	y	-5804070.2578	-5804070.1975	-5804070.2688	-0.0110
	z	-1796893.9701	-1796893.9689	-1796893.9682	0.0019
CHAT	x	-4590670.9604	-4590670.9236	-4590670.9634	-0.0030
	y	-275482.9148	-275483.0412	-275482.9124	0.0024
	z	-4404596.7635	-4404596.7379	-4404596.7569	0.0066
COCO	x	-741950.0824	-741950.2982	-741950.0894	-0.0070
	y	6190961.6561	6190961.6329	6190961.6687	0.0126
	z	-1337768.5172	-1337768.3978	-1337768.5171	0.0001
FAIR	x	-2281621.4718	-2281621.4654	-2281621.4721	-0.0003
	y	-1453595.7977	-1453595.9585	-1453595.7924	0.0053
	z	5756961.8819	5756961.8939	5756961.8796	-0.0023
GOLD	x	-2353614.2057	-2353614.0721	-2353614.2041	0.0016
	y	-4641385.3819	-4641385.5212	-4641385.3792	0.0027
	z	3676976.4306	3676976.3979	3676976.4196	-0.0110
GUAM	x	-5071312.7950	-5071312.9313	-5071312.7964	-0.0014
	y	3568363.5147	3568363.3193	3568363.5360	0.0213
	z	1488904.3023	1488904.3602	1488904.3042	0.0019
IRKT	x	-968332.2369	-968332.4038	-968332.2330	0.0039
	y	3794425.4205	3794425.2905	3794425.4063	-0.0142
	z	5018167.7363	5018167.7957	5018167.7105	-0.0258
KOKB	x	-5543838.1367	-5543838.0935	-5543838.1474	-0.0107
	y	-2054587.1392	-2054587.3805	-2054587.1410	-0.0018
	z	2387809.7443	2387809.7253	2387809.7387	-0.0056
POL2	x	1239971.5384	1239971.3449	1239971.5377	-0.0007
	y	4530790.0758	4530790.0380	4530790.0695	-0.0063
	z	4302578.7682	4302578.8635	4302578.7535	-0.0147
MDVO	x	2844672.2450	2844672.1389	2844672.2577	0.0127
	y	2161070.1202	2161070.1397	2161070.1251	0.0049
	z	5266363.8282	5266363.9500	5266363.8569	0.0287
SHAO	x	-2831733.3272	-2831733.5220	-2831733.3344	-0.0072
	y	4675666.0270	4675665.8700	4675666.0307	0.0037
	z	3275369.4809	3275369.5658	3275369.4823	0.0014
USUD	x	-3855263.0070	-3855263.1495	-3855263.0026	0.0044
	y	3427432.5322	3427432.3314	3427432.5321	-0.0001
	z	3741020.3343	3741020.3948	3741020.3335	-0.0008
YAR1	x	-2389025.6224	-2389025.7818	-2389025.6264	-0.0040
	y	5043316.9005	5043316.8090	5043316.8808	-0.0197
	z	-3078530.6640	-3078530.5489	-3078530.6444	0.0196

The transformation accuracy : ± ***0.10525415D-01***

The adopted coordinate system in table 1.1 is the geocentric rectangular coordinate system, and the unit is the meter. There are 13 igs sites listed in the first column based on which the transformation seven parameters have been determined. In table 1.2, we give out the transformation seven parameters for every day from 19 Nov. 1998 to 28 Nov. 1998.

Table 1.2 : Transformation seven parameters

	dx	dy	dz	D	r1	r2	r3
1	0.2170D-03	0.1779D-01	-.4216D-01	0.1391D-08	-.1482D-07	0.2281D-07	-.1449D-06
2	0.7139D-02	0.1949D-01	-.2570D-01	0.2982D-09	-.1472D-07	0.1960D-07	-.1042D-06
3	0.4381D-02	0.2117D-01	-.5164D-01	0.7310D-09	-.1162D-07	0.7110D-08	-.3464D-07
4	-.2486D-01	0.3030D-01	-.3254D-01	0.6894D-09	-.1464D-07	0.1511D-07	-.1018D-06
5	-.6861D-02	0.2207D-01	-.3284D-01	0.1959D-09	-.1890D-07	0.2086D-07	-.1614D-06
6	-.2221D-02	0.9279D-02	-.6174D-01	0.6215D-09	-.1475D-07	0.6693D-09	-.4667D-07
7	-.1346D-01	0.1344D-01	-.3718D-01	0.1413D-08	-.1902D-07	0.1013D-07	-.1209D-06
8	-.4142D-02	0.1434D-01	0.8294D-02	0.4843D-09	-.1599D-07	0.3918D-08	-.9490D-07
9	-.1897D-01	0.9793D-02	-.2512D-01	0.9398D-09	-.1579D-07	-.2693D-08	-.5030D-07
10	-.1959D-01	0.2384D-01	-.3172D-01	0.1804D-08	-.1430D-07	-.1133D-07	-.3404D-08

where, the first raw is corresponding to the transformation seven parameters on the day of 19 Nov. 1998 and so on.

3) The method of the precise point positioning was used. This is a very powerful strategy for estimating a single station. It uses fixed orbits, satellite clocks and time, polar motion, earth rotation estimates as well as satellite eclipse information from thorough analysis at JPL using a global fiducial network. With this method, we can only estimate one station at a time. So the computing time will not be increased geometrically with the number of stations.

The main shortcoming is that this method is unable to account for correlation among stations. Also, the orbits are assumed to be perfect, which is obviously not the case. But these shortcomings can be basically overcome after doing the seven-parameter transformation.

2. RESULTS AND ANALYSIS

According to the analysis program mentioned above, we have obtained the geocentric spherical coordinates for APRG97 and APRG98 GPS sites and igs sites included in this treating. Their site coordinates and s are listed in table 2 ana table 3. The RMS scatter of the station components north, east and up resulting from the multiday analysis for APRG97 and APRG 98 are shown in figure ' Scatter in North, East and Up direction for APRG97' and in figure ' Scatter in North, East and Up direction for APRG98' respectively.

Table 2 : APRG 97 GPS station coordinates at epoch 1997.788

Site	Latitude	Longitude	Radius (m)			
0029	N38 55 20.59479	E141 12 14.11704	6369842.557	0.00005	0.00007	0.00316
0073	N35 18 31.25490	E133 41 56.40281	6371041.788	0.00002	0.00008	0.00348
0745	N26 0 59.75808	E127 49 34.24278	6374103.132	0.00002	0.00009	0.00416
0746	N25 48 9.36456	E131 17 26.42167	6374141.542	0.00002	0.00006	0.00347
2001	N43 20 12.07750	E141 50 41.19456	6368157.001	0.00002	0.00010	0.00445
2004	N31 15 15.67794	E130 52 42.86410	6372493.819	0.00002	0.00006	0.00505
3009	N35 46 21.84652	E140 39 33.24876	6370871.017	0.00002	0.00010	0.00427
6006	N33 24 2.73115	E135 56 13.03801	6371731.388	0.00003	0.00009	0.00339
ALBH	N48 11 55.06449	W123 29 14.89125	6366258.454	0.00004	0.00008	0.00151
ALIC	S23 31 44.22089	E133 53 7.85282	6375317.736	0.00005	0.00008	0.00288
ANKR	N39 41 53.32133	E 32 45 30.49207	6370362.200	0.00007	0.00008	0.00277
AREQ	S16 21 40.47067	W 71 29 34.05004	6378921.196	0.00006	0.00013	0.00568
AUCK	S36 25 7.72170	E174 50 3.78738	6370707.885	0.00008	0.00007	0.00443
BAHR	N26 3 25.04829	E 50 36 29.31711	6373976.978	0.00008	0.00008	0.00369
BAKO	S 6 26 52.68787	E106 50 56.07240	6378024.209	0.00006	0.00009	0.00513
BEIJ	N39 25 10.91061	E115 53 32.93788	6369575.847	0.00004	0.00007	0.00415

CAS1 S66 8 28.74635 E110 31 10.93967 6360258.788 0.00009 0.00051 0.01015
CC06 N43 35 54.16025 E125 26 40.24891 6368213.588 0.00002 0.00005 0.00326
CEDU S31 41 39.74967 E133 48 35.38059 6372357.339 0.00004 0.00009 0.00198
CHAT S43 45 48.66208 W176 33 57.01884 6367937.128 0.00008 0.00009 0.00265
COCO S12 6 33.02213 E 96 50 2.27768 6377156.154 0.00006 0.00009 0.00531
FAIR N64 49 48.68297 W147 29 57.25909 6360923.459 0.00004 0.00007 0.00207
FORT S 3 51 5.64342 W 38 25 32.20464 6378059.485 0.00008 0.00017 0.00656
GALA S 0 44 15.80847 W 90 18 13.03865 6378140.884 0.00007 0.00012 0.00150
GOLD N35 14 36.99157 W116 53 21.29481 6371978.781 0.00004 0.00014 0.00392
GUAM N13 30 6.12304 E144 52 6.10233 6377167.665 0.00002 0.00019 0.00540
HOB2 S42 36 46.47006 E147 26 19.43937 6368348.901 0.00004 0.00009 0.00162
IISC N12 56 13.01252 E 77 34 13.34279 6377903.740 0.00011 0.00018 0.00474
IRKT N52 1 57.13305 E104 18 58.45597 6365323.159 0.00005 0.00007 0.00363
JAB1 S12 34 36.53369 E132 53 38.02425 6377200.476 0.00007 0.00009 0.00591
KARR S20 51 11.13568 E117 5 49.87853 6375524.430 0.00006 0.00007 0.00442
KERG S49 9 40.19244 E 70 15 19.87829 6365943.731 0.00010 0.00012 0.00381
KIT3 N38 56 47.43159 E 66 53 7.59474 6370283.966 0.00009 0.00010 0.00644
KOKB N21 59 32.38710 W159 39 53.72519 6376292.406 0.00004 0.00004 0.00562
KSTU N55 48 52.56916 E 92 47 37.78317 6363690.245 0.00007 0.00017 0.00185
KUAL N 5 17 0.54641 E103 8 20.92416 6378009.750 0.00005 0.00020 0.01139
KUNM N24 52 56.53448 E102 47 49.89580 6376321.528 0.00008 0.00020 0.00671
KWJ1 N 8 39 52.93650 E167 43 48.87836 6377687.506 0.00010 0.00008 0.00799
LADA N28 8 1.35718 E 55 53 40.82559 6374279.902 0.00004 0.00007 0.00542
LHAS N29 29 32.04816 E 91 6 14.35300 6376558.952 0.00005 0.00013 0.00890
LHAS N29 29 32.04816 E 91 6 14.35300 6376558.952 0.00005 0.00013 0.00890
MAC1 S54 19 2.61206 E158 56 9.00151 6363997.169 0.00011 0.00011 0.00237
MADR N40 14 21.50615 W 4 14 58.77591 6370016.577 0.00009 0.00017 0.00878
MANA N 1 37 15.41963 E124 54 17.28176 6323115.850 0.00009 0.00017 0.00878
MARI N35 32 53.38857 E 51 48 43.68576 6372698.719 0.00008 0.00015 0.00311
MDO1 N30 30 43.03443 W104 0 53.97194 6374608.375 0.00004 0.00008 0.00450
MDVO N55 50 56.10648 E 37 13 24.91267 6363723.202 0.00005 0.00012 0.00394
MKEA N19 40 44.67933 W155 27 22.80901 6379455.788 0.00003 0.00016 0.00495
MORE S 9 22 19.45463 E147 11 12.20427 6377683.824 0.00007 0.00010 0.00506
NILO N32 14 37.67066 E 48 20 8.95964 6372163.916 0.00007 0.00008 0.00257
NLIB N41 34 49.67989 W 91 34 29.61821 6368898.380 0.00004 0.00009 0.00303
NTUS N 1 20 12.46637 E103 40 47.84055 6378200.707 0.00007 0.00021 0.00621
ONSA N57 13 13.30265 E 11 55 31.85524 6363043.906 0.00005 0.00010 0.00265
PARE S 3 57 5.49702 E119 39 0.01594 6378169.414 0.00007 0.00014 0.00897
PERT S31 37 47.51479 E115 53 6.89279 6372246.919 0.00005 0.00005 0.00354
POL2 N42 29 17.09059 E 74 41 39.34547 6370068.453 0.00005 0.00007 0.00309
REIH N28 45 23.01743 E 51 4 54.15461 6373222.980 0.00006 0.00013 0.00545
ROSE N32 8 22.11728 E 53 49 20.19913 6373287.455 0.00008 0.00010 0.00299
SAMP N 3 35 50.74959 E 98 42 52.98252 6378054.646 0.00003 0.00018 0.00528
SANT S32 58 27.66493 W 70 40 6.80072 6372502.965 0.00007 0.00027 0.00780
SHAO N30 55 46.90936 E121 12 1.59095 6372488.642 0.00003 0.00010 0.00269
SUWN N37 5 24.76611 E127 3 15.25910 6370416.788 0.00002 0.00011 0.00356
TAEJ N36 11 27.02303 E127 21 57.88407 6370733.966 0.00002 0.00008 0.00287
TAHI S17 27 57.71444 W149 36 33.75990 6376275.785 0.00005 0.00006 0.00382
TAIW N24 52 26.95027 E121 32 11.54841 6374381.699 0.00003 0.00036 0.00190
TAWA N 4 13 22.61792 E117 58 42.79352 6378472.405 0.00002 0.00031 0.00456
TIDB S35 13 3.75410 E148 58 47.98860 6371666.619 0.00008 0.00012 0.00598
TOW2 S19 8 58.96193 E147 3 20.47000 6375913.596 0.00005 0.00009 0.00425
TSKB N35 55 21.52653 E140 5 14.98835 6370819.123 0.00001 0.00007 0.00266
URUM N43 35 40.59996 E 87 37 54.50358 6368805.830 0.00005 0.00009 0.00313
USUD N35 57 0.22217 E138 21 43.35695 6372250.769 0.00005 0.00003 0.00297
WETT N48 57 13.36159 E 12 52 44.06811 6366613.283 0.00006 0.00007 0.00258
WINA N 1 26 1.53840 E124 50 20.51784 6378321.041 0.00009 0.00020 0.00929
WUHN N30 21 48.69691 E114 21 26.13504 6372678.156 0.00003 0.00005 0.00235
XIAN N34 11 22.48250 E109 13 17.36867 6371825.069 0.00003 0.00008 0.00128
YAS1 N35 6 41.14059 E 58 27 48.96875 6372207.242 0.00007 0.00006 0.00246
YELL N62 19 22.43007 W114 28 50.51679 6361528.686 0.00005 0.00017 0.00131
ZECK N43 35 46.33179 E 41 33 54.23030 6369107.775 0.00005 0.00014 0.00216
ZWEN N55 31 11.67498 E 36 45 31.05315 6363787.475 0.00003 0.00009 0.00388

Table 3 : The APRG98 GPS station coordinates at 1998.898

site	Latitude	Longitude	Radius(m)			
0029	N38 55 20.59463	E141 12 14.11653	6369842.534	0.00004	0.00005	0.00598
0073	N35 18 31.25444	E133 41 56.40367	6371041.771	0.00002	0.00004	0.00255
0745	N26 0 59.75677	E127 49 34.24426	6374103.106	0.00003	0.00006	0.00234
0746	N25 48 9.36534	E131 17 26.42035	6374141.534	0.00003	0.00004	0.00381
2001	N43 20 12.07705	E141 50 41.19487	6368157.017	0.00003	0.00006	0.00504
2003	N26 56 23.43287	E142 11 4.49569	6373938.859	0.00005	0.00010	0.00275
2004	N31 15 15.67701	E130 52 42.86560	6372493.801	0.00004	0.00004	0.00195
3009	N35 46 21.84617	E140 39 33.24847	6370871.002	0.00002	0.00004	0.00238
6006	N33 24 2.73099	E135 56 13.03768	6371731.377	0.00001	0.00004	0.00220
ALIC	S23 31 44.21901	E133 53 7.85403	6375317.735	0.00006	0.00005	0.00438
AREQ	S16 21 40.47012	W 71 29 34.04934	6378921.177	0.00006	0.00011	0.00406
AUCK	S36 25 7.72075	E174 50 3.78762	6370707.895	0.00005	0.00006	0.00195
BAKO	S 6 26 52.68829	E106 50 56.07318	6378024.189	0.00003	0.00011	0.00403
BEIJ	N39 25 10.91016	E115 53 32.93922	6369575.722	0.00002	0.00004	0.00224
BINT	N 3 14 22.99212	E113 4 1.98965	6378117.173	0.00002	0.00028	0.00303
CCBS	N 1 19 58.91101	E103 57 32.50100	6378162.341	0.00003	0.00008	0.00417
CEDU	S31 41 39.74779	E133 48 35.38198	6372357.359	0.00006	0.00006	0.00245
CHAT	S43 45 48.66134	W176 33 57.02087	6367937.140	0.00006	0.00009	0.00288
CHON	N13 2 8.54259	E101 2 40.95740	6377095.294	0.00004	0.00002	0.00423
CHUL	N13 38 49.00570	E100 31 56.26069	6376926.824	0.00003	0.00011	0.00772
COCO	S12 6 33.02037	E 96 50 2.27873	6377156.190	0.00003	0.00009	0.00370
D001	N 5 14 53.79384	E115 11 7.15459	6378070.655	0.00002	0.00005	0.00327
D004	N 4 13 22.66358	E117 58 42.59231	6378472.776	0.00006	0.00008	0.00681
D005	N 6 21 5.84243	E116 29 9.89780	6378069.265	0.00007	0.00013	0.00274
DOP1	N 3 0 16.33589	E101 26 44.87527	6378139.047	0.00003	0.00025	0.00568
DOP2	N 1 22 2.32095	E103 36 29.48832	6378216.383	0.00002	0.00009	0.00595
DOP3	N 3 26 26.61746	E102 37 18.93821	6378328.890	0.00002	0.00006	0.00937
DOP4	N 5 59 54.84330	E102 19 14.68391	6378009.875	0.00003	0.00006	0.00411
DOP5	N 6 5 56.14100	E100 23 6.57533	6377884.324	0.00005	0.00018	0.00810
FAIR	N64 49 48.68228	W147 29 57.25988	6360923.468	0.00002	0.00009	0.00204
GALA	S 0 44 15.80826	W 90 18 13.03660	6378140.917	0.00011	0.00025	0.00786
GOLD	N35 14 36.99126	W116 53 21.29531	6371978.789	0.00004	0.00008	0.00736
GUAM	N13 30 6.12284	E144 52 6.10147	6377167.679	0.00006	0.00012	0.00664
HOB2	S42 36 46.46829	E147 26 19.43989	6368348.902	0.00005	0.00006	0.00176
HOKI	S42 31 16.14192	E170 59 3.53503	6368395.640	0.00005	0.00008	0.00339
HOUA	N20 8 13.70981	E100 26 13.94890	6375964.465	0.00004	0.00008	0.00198
IISC	N12 56 13.01340	E 77 34 13.34416	6377903.737	0.00007	0.00007	0.01054
IRKT	N52 1 57.13278	E104 18 58.45734	6365323.139	0.00004	0.00014	0.00201
KARR	S20 51 11.13355	E117 5 49.87987	6375524.427	0.00013	0.00011	0.00805
KERG	S49 9 40.19250	E 70 15 19.87859	6365943.724	0.00009	0.00016	0.00627
KHON	N14 1 41.10610	E105 51 8.12894	6376948.720	0.00003	0.00009	0.00255
KOKB	N21 59 32.38786	W159 39 53.72725	6376292.409	0.00005	0.00005	0.00389
KUAL	N 5 17 0.54640	E103 8 20.92463	6378009.759	0.00003	0.00024	0.00513
KWJ1	N 8 39 52.93704	E167 43 48.87566	6377687.492	0.00006	0.00009	0.00644
LABG	S 6 26 51.43663	E106 50 55.97711	6378023.656	0.00005	0.00013	0.00434
LAE1	S 6 37 45.96312	E146 59 35.47099	6377990.923	0.00003	0.00013	0.00316
LAKX	N18 4 18.30826	E104 59 1.88163	6376569.571	0.00003	0.00005	0.00388
LAND	N11 28 25.14413	E104 54 49.02466	6377292.873	0.00009	0.00010	0.00191
LHAS	N29 29 32.04865	E 91 6 14.35437	6376558.959	0.00007	0.00014	0.00421
MARI	N35 32 53.38910	E 51 48 43.68690	6372698.489	0.00003	0.00012	0.00276
MDVO	N55 50 56.10703	E 37 13 24.91408	6363723.179	0.00003	0.00008	0.00225
MMA8	N14 30 16.64896	E120 58 21.76152	6376845.820	0.00005	0.00009	0.00690
MORE	S 9 22 19.45284	E147 11 12.20572	6377690.174	0.00004	0.00010	0.00389
MSAN	N 5 48 12.82250	E118 7 14.10084	6378050.797	0.00002	0.00009	0.00446
MTAW	N 4 14 3.63319	E117 52 53.93021	6378092.722	0.00003	0.00009	0.00536
OUSD	S45 40 37.73491	E170 30 39.31580	6367191.268	0.00005	0.00010	0.00361
P075	N22 8 57.63387	E114 4 34.70412	6375200.474	0.00004	0.00009	0.00462
PARE	S 3 57 5.49742	E119 39 0.01720	6378169.282	0.00006	0.00009	0.00890
PBIT	N 1 25 55.33857	E125 11 36.29414	6378196.341	0.00005	0.00024	0.00850
PDAY	S 6 3 25.23426	E106 52 40.69311	6377917.704	0.00011	0.00019	0.01420
PENH	N11 29 54.24810	E104 55 3.28084	6377298.407	0.00004	0.00010	0.00323

PERT	S31 37 47.51284	E115 53 6.89409	6372246.920	0.00005	0.00007	0.00288
PHON	N21 33 9.60751	E102 6 4.54352	6376611.970	0.00003	0.00007	0.00163
PHUK	N 7 42 27.91008	E 98 18 12.94598	6377748.635	0.00003	0.00014	0.00511
PHUT	N16 30 33.96887	E106 30 2.21115	6376660.869	0.00005	0.00006	0.00784
POL2	N42 29 17.09071	E 74 41 39.34676	6370068.449	0.00004	0.00006	0.00203
PSOR	S 0 52 17.42437	E131 14 50.46994	6378210.362	0.00010	0.00067	0.00409
QT02	N20 34 8.00729	E106 47 29.19511	6375493.549	0.00003	0.00008	0.00344
QT04	N10 17 6.29192	E107 5 12.17135	6377474.834	0.00005	0.00014	0.00352
REIH	N28 45 23.01857	E 51 4 54.15554	6373222.873	0.00003	0.00012	0.00263
RP01	N14 26 38.18085	E121 2 23.12878	6376869.560	0.00005	0.00017	0.00401
ROSE	N32 8 22.11792	E 53 49 20.20001	6373287.283	0.00002	0.00010	0.00225
RTSD	N13 40 17.97717	E100 30 26.67398	6376918.764	0.00005	0.00019	0.00878
SAMN	N20 17 50.88594	E104 2 35.50766	6376534.839	0.00002	0.00008	0.00277
SAMP	N 3 35 50.74962	E 98 42 52.98388	6378054.480	0.00005	0.00007	0.00499
SANT	S32 58 27.66432	W 70 40 6.79985	6372502.959	0.00007	0.00019	0.00524
SHAO	N30 55 46.90882	E121 12 1.59234	6372488.650	0.00001	0.00004	0.00281
SIEM	N13 19 21.79526	E103 48 55.59711	6376993.856	0.00004	0.00005	0.00228
STUE	N13 26 35.68267	E105 58 15.53053	6377013.246	0.00004	0.00012	0.00361
SUVA	S18 1 56.42726	E178 25 30.89081	6376151.169	0.00005	0.00013	0.00636
SUWN	N37 5 24.76563	E127 3 15.26037	6370416.787	0.00002	0.00006	0.00164
SVAY	N11 1 10.64666	E105 47 24.81917	6377348.418	0.00012	0.00018	0.00461
T012	N 3 11 50.04989	E113 4 59.31879	6378275.124	0.00005	0.00004	0.00780
T030	N 1 34 31.74956	E110 13 7.36056	6378267.984	0.00004	0.00023	0.00578
TAEJ	N36 11 27.02247	E127 21 57.88546	6370733.971	0.00003	0.00006	0.00359
TAWA	N 4 13 22.61707	E117 58 42.79386	6378472.394	0.00002	0.00006	0.00374
TG75	N 1 19 3.11782	E103 54 11.31628	6378186.227	0.00006	0.00020	0.00737
TGET	N 6 11 5.40951	E102 6 19.66657	6377887.109	0.00003	0.00018	0.00541
TIDB	S35 13 3.75233	E148 58 47.98921	6371666.625	0.00004	0.00013	0.00156
TKIN	N 5 56 38.27851	E116 5 36.91217	6377958.176	0.00002	0.00011	0.00647
TKLA	N 3 1 34.22630	E101 21 31.21237	6378076.537	0.00005	0.00016	0.00939
TKUC	N 1 34 21.35061	E110 25 21.64593	6378158.292	0.00003	0.00009	0.00851
TOW2	S19 8 58.96013	E147 3 20.47120	6375913.611	0.00003	0.00008	0.00344
TTAW	N 4 13 1.60862	E117 52 49.92561	6378081.225	0.00003	0.00009	0.00673
URMQ	N43 36 56.68112	E 87 36 2.38937	6368793.082	0.00012	0.00024	0.00352
USUD	N35 57 0.22196	E138 21 43.35688	6372250.762	0.00002	0.00004	0.00292
VANI	S 2 40 0.66719	E141 18 15.65894	6378172.625	0.00004	0.00007	0.00581
VANU	S16 19 41.07373	E179 24 45.60560	6376606.024	0.00006	0.00014	0.00605
VIEN	N17 54 45.29449	E102 30 56.10778	6376297.387	0.00003	0.00006	0.00189
VITI	S17 32 24.10613	E177 23 36.11455	6376272.810	0.00002	0.00012	0.00634
WUHN	N30 21 48.69669	E114 21 26.13638	6372680.529	0.00003	0.00007	0.00251
XIAN	N34 11 22.48196	E109 13 17.36998	6371825.081	0.00003	0.00005	0.00460
YAR1	S28 53 0.61373	E115 20 49.10773	6373369.571	0.00005	0.00005	0.00320
YAS1	N35 6 41.14093	E 58 27 48.96985	6372207.054	0.00002	0.00010	0.00258

In table 2 and table 3, the unit is degree, minute and arc second for latitude and longitude, and is meter for radius respectively. The unit of accuracy is arc second for latitude and longitude and meter for radius.

It can be seen from table 2 and table 3 that the accuracy for most sites from the multiday solution is following:

1 – 2 mm for north component

2 – 3 mm for east component

5 –10 mm for vertical component

There are about 50 sites which were measured repeatedly, their horizontal velocities have been determined preliminary. (See Fig. 'Site Horizontal Velocities from APRG97 and APRG98 GPS DATA' and table 4).

Table 4 : The velocities determined by means of GPS data of APRG97 and APRG98

ID	Site	Latitude (Deg.)	Longt itude (Deg.)	Vns(mm/yr)	Vew (mm/yr)
01	0029	38.9	141.2	-4.5	-11.1
02	0073	35.3	133.7	-12.9	19.7
03	0745	26.0	127.8	-36.8	37.3
04	0746	25.8	131.3	22.2	-32.4
05	2001	43.3	141.8	-12.6	6.3
06	2004	31.3	130.9	-26.1	36.0
07	3009	35.8	140.7	-10.7	-6.8
08	6006	33.4	135.9	-4.2	-6.1
09	ALIC	-23.5	133.9	52.8	31.2
10	AREQ	-16.4	-71.5	15.4	18.9
11	AUCK	-36.4	174.8	26.7	5.4
12	BAKO	-6.4	106.8	-11.5	21.5
13	BEIJ	39.4	115.9	-12.6	29.1
14	CEDU	-31.7	133.8	52.8	33.2
15	CHAT	-43.8	-176.6	20.8	-41.2
16	COCO	-12.1	96.8	49.4	38.8
17	FAIR	64.8	-147.5	-19.4	-9.4
18	GALA	-0.7	-90.3	5.9	57.6
19	GOLD	35.2	-116.9	-8.7	-11.5
20	GUAM	13.5	144.9	-5.6	-23.5
21	HOB2	-42.6	147.4	49.7	10.7
22	IISC	12.9	77.6	33.9	40.0
23	IRKT	52.0	104.3	-7.6	23.7
24	JAB1	-12.6	132.9	59.0	50.4
25	KARR	-20.9	117.1	56.6	35.1
26	KERG	-49.2	70.3	-1.7	5.5
27	KOKB	22.0	-159.7	31.4	-53.6
28	KUAL	5.3	103.1	-0.3	19.6
29	KWJ1	8.7	167.7	15.2	-74.9
30	LABG	-6.4	106.8	-16.9	15.3
31	LAHS	29.5	91.1	16.8	43.5
32	MAR1	35.5	51.8	14.9	26.0
33	MDVO	55.8	37.2	15.4	22.2
34	MORE	-9.4	147.2	50.3	40.2
35	PARE	-3.9	119.6	10.7	37.3
36	PERT	-31.6	115.9	54.7	31.1
37	POLI	42.5	74.7	3.4	26.7
38	REIM	28.8	51.1	32.3	22.4
39	ROSE	32.1	53.8	14.0	20.9
40	SAMP	3.6	98.7	0.8	38.1
41	SANT	-33.0	-70.7	-17.1	20.5
42	SHAO	30.9	121.2	-15.2	33.5
43	SUWN	37.1	127.1	-13.5	28.4
44	TAEJ	36.2	127.4	-15.7	31.4
45	TAWA	4.2	118.0	-23.9	9.5
46	TIDB	-35.2	149.0	49.7	14.0
47	TOWI	-19.1	147.1	50.5	31.8
48	USUD	36.0	138.4	-5.9	-1.6
49	WUHN	30.4	114.4	-6.2	32.5
50	XIAN	34.2	109.2	-15.2	30.4
51	YAR1	-28.9	115.3	53.19	32.7
52	YAS1	35.1	58.5	9.6	25.3

Based on following formula:

$$s_v = \frac{s_r}{T}\sqrt{\frac{12(n-1)}{n(n+1)}}$$

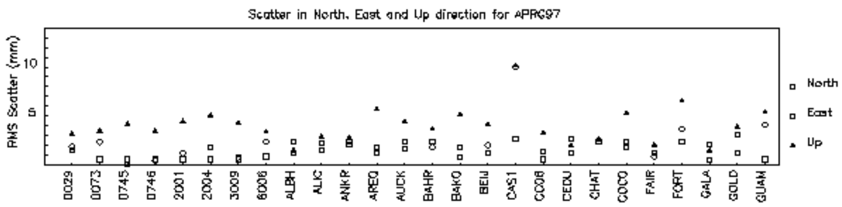
The accuracy of the velocities in table 4 is about 4mm/yr, where s_r is the accuracy for single solution (it is taken as 3mm), n is the number of single solutiona (it is taken as 2), T is the time span (it is equal to 1.109 year here)

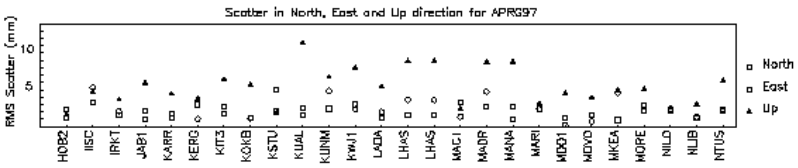
CONCLUSION

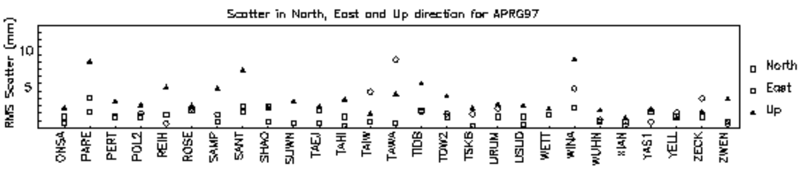
1) The two campaigns carried by APRG were successful for getting high precision coordinates;
2) The positioning accuracy reached for horizontal position component is 1-5mm and for the height component is about 5-10mm.
3) From APSG97 and APRG98 GPS data, the site horizontal velocity about 50 stations have been determined preliminary, the accuracy of horizontal velocity is about 4mm/yr

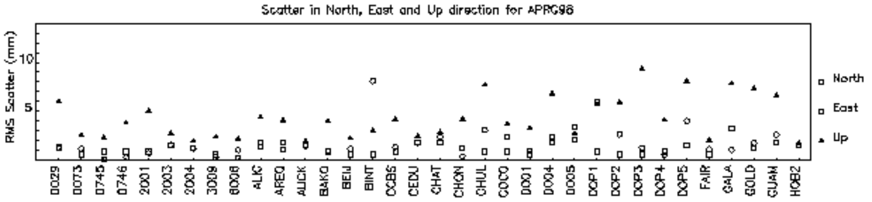
REFERENCE

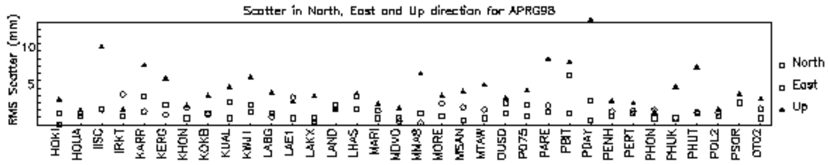
Michael, H., et al., Global Geodesy Using GPS without Fiducial Site, Geophysical Research Letters, Vol. 19. No. 2, 131-134, 1992.

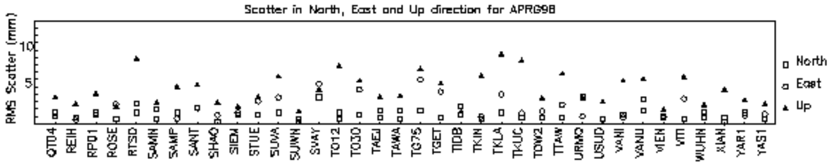


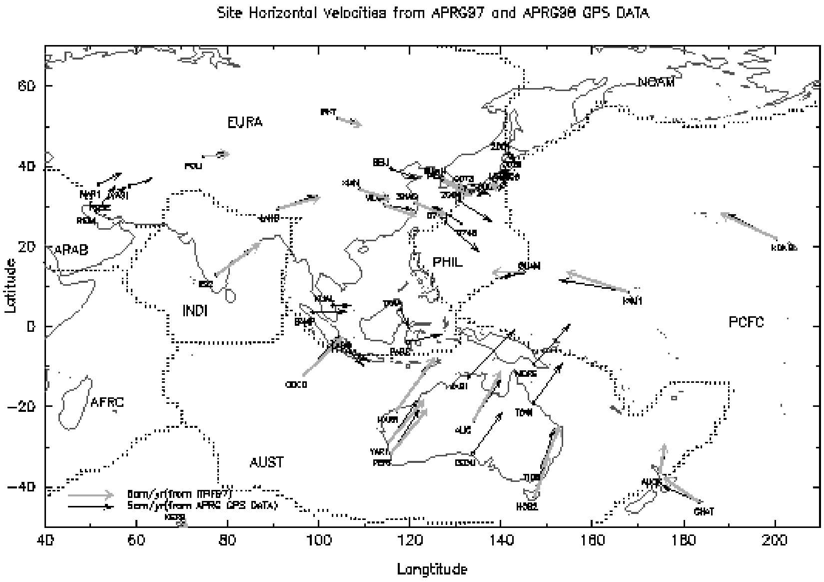





Scatter in North, East and Up direction for APRG98
RMS Scatter (mm)
North
East
Up


Scatter in North, East and Up direction for APRG98
RMS Scatter (mm)
North
East
Up


Scatter in North, East and Up direction for APRG98
RMS Scatter (mm)
North
East
Up


Site Horizontal Velocities from APRG97 and APRG98 GPS DATA
Latitude
Longtitude
EURA
NOAM
ARAB
PHIL
INDI
PCFC
AFRC
AUST
8cm/yr(from ITRF97)
5cm/yr(from APRG GPS DATA)

GPS RESULTS FOR APRGP98

CECEP SUBARYA/ INDONESIA

GPS DATA ANALYSIS - PRELIMINARY RESULTS
ASIA PACIFIC REGIONAL GEODETIC PROJECT 1997 & 1998

Campaign Observation Periods

1997 : GPS week 927 (12th to 18th October)

1998 : GPS week 984 day 4 to 985 day 6
(19th to 29th November)

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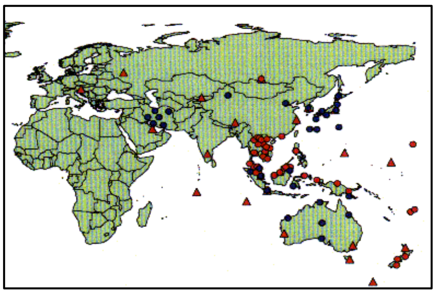

– **Number of Participating Countries - sites**

	1997	1998		1997	1998
1. Australia	5	5	13. Philippines	-	2
2. Cambodia	-	6	14. Singapore	-	3
3. China	4	3	15. South Korea	1	1
4. Fiji	-	3	16. Thailand	-	4
5. Hong Kong	-	1	17. Vietnam	-	4
6. Indonesia	6	7		33	92
7. Iran	6	6			
8. Japan	8	9			
9. Lao	-	7			
10. Malaysia	2	25			
11. New Zealand	-	3			
12. Papua New Guinea	1	3			

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– **GPS Data Processing**

- Processed using the GAMIT Ver.9.88, parameters estimated :
  - * station coordinates,
  - * satellite state vector
  - * a residual tropospheric delay parameter
  - * phase ambiguities
  - * "loosely" constraints
- Combined daily solutions into GLOBK Ver.5.02I/Ver.4.1
  a network adjustment Kalman filter program

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– **Reference Frames**

- **ITRF96 (positions and veloities)**
- **solid earth tides**
- **ocean tide loading**
- **precession IAU 1976**
- **nutation IAU 1980**
- **EOP → IERS Bulletin B**

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– **GAMIT solutions strategy**

- GPS data APRGP98 campaign is 92 stations (MAXSIT=35)
  network processing devided into 5 (five) groups :

* regional 1 : Australia, New Zealand, PNG, Fiji, Indonesia, Philippines
with the nearest IGS global stations.
* regional 2 : Indonesia, Malaysia, Singapore, Philippines
with the nearest IGS global stations.
* regional 3 : Indonesia (bako,pare,samp), Malaysia (tawa,kual), Japan, China, Hong Kong, South Korea, Lao, Vietnam, Cambodia, Thailand, with the nearest IGS global stations.
* regional 4 : Iran, with the nearest IGS global stations.
* regional 5 : Common Stations of APRGP97 and APRGP98,
with the nearest IGS stations

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– **Regional daily solutions each group**

- To provide a tie between global and regional solutions at least 3 (three) IGS global stations are common.

  * Southern Hemisphere :

  yar1, tid2=tidb, mac1, auck, coco, bako

  * Northern Hemisphere :

  bahr, pol2, zwen, graz, iisc, lhas, shao, tskb, guam, kwj1

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Cecep Subarya

– **Quality Assurance**

- Orbit integration with an IGS precise orbit (sp3), each day of solution
  * prefit RMS (m) : 1.000→ postfit RMS (m) ~ 0.025

- Normalised root mean square, **nrms** , the normal range is between 0.2 and 0.4 ;
  * regional 1 of solution from 0.27 to 0.30
  * regional 2 of solution from 0.32 to 0.35
  * regional 3 of solution from 0.25 to 0.30
  * regional 4 of solution from 0.15 to 0.16
  * regional 5 of solution from 0.24 to 0.27

PCGIAP Working Group 1 Workshop, Ho Chi Minh City, 12 - 13 July 1999

Cecep Subarya

– **GLOBK solutions strategy**

- The global and regional solution approach ;
  * **SIO global solution (higs1a.yyddd),**
  albh, algo, amc2, aoml, asc1, bako, brmu, cr01, drao, elat, fair,fort, glsv, gol2, hark, hrao, jplm, kely, kokb, kosg, kour, mad2, mali, mas1, mkea, nrc1, nya1, onsa, pots, prds, sch2, stjo, suth, thu1, tr01, tskb, wes2, whit, wrst, wtzr, yell, zwen. (42 stations)
  * **SIO global solution (higs2a.yyddd),**
  alic, areq, auck, bahr, cas1, chat, coco, dav1, dgar, eisl, fort, gala, guam, hark, hob2, iisc, irkt, jplm, kokb, kwj1, lhas, mac1, mago, maw1, mcm4, noum, ntus, pert, petp, sant, shao, suwn, taej, tid2, tskb, usud, wtzr, wuhn, xian, yakz, yar1, zwen. (42 stations)
  * **Regional daily sol. each group (hapr1a.yyddd ...hapma.yyddd), with the nearest IGS stations**: yar1, tid2, mac1, auck, coco, bahr, pol2, zwen, graz, iisc, lhas, shao, tskb.

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Cecep Subarya

– **GLOBK solutions strategy** ……………. continued

- The global and regional solution approach ;
  The type of receivers of IGS global stations included in solutions are Rogue except : bako, elat, glsv, taej, noum (trimble 4000ssi) and bahr, mago, petp, yakz (ashtech z12).

- Quality assurance ;
  * Daily loosely-constrained GAMIT solution combine in GLOBK to give an overall solution.
  * The χ^2 statistic is a measure of the consistency the data fit together
  * Theoretically, the χ^2 should be unity.
  * Solution is acceptable if the χ^2 values should be below 10.
  * APRGP97 and APRGP98 solutions fit together (acceptable)

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Cecep Subarya

– **Station Coordinate repeatability**

- The combined solutions APRGP97 (7 daily solutions) and APRGP98 (10 daily solutions)→ ITRF96 epoch 1998.9076;

Common stations (APRGP97 & APRGP98)

* the horizontal position component (East, North) : 1.0 mm rms
* the vertical position component (Up) : 2.0 mm rms
* the velocity estimates is not being analyze yet

APRGP98

* the horizontal position components (East, North) : 5.0 mm rms
* the vertical position component (Up) : 8.0 mm rms

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Cecep Subarya

– **Vertical Datum**

- There are 3 (three) stations in APRGP98 campaign on benchmark of Tide Gauge Stations (Indonesia sites) : PDAY (Jakarta / Jawa) PBIT (Bitung / North Sulawesi) and PSOR (Sorong / Irian Jaya)

$$h_{ell} = H_{ort} + N$$

* h_{ell} , reference ellipsoid WGS84

Preliminary computation using EGM96, the different between H_{grav} and H_{ort} ~ 2 meter

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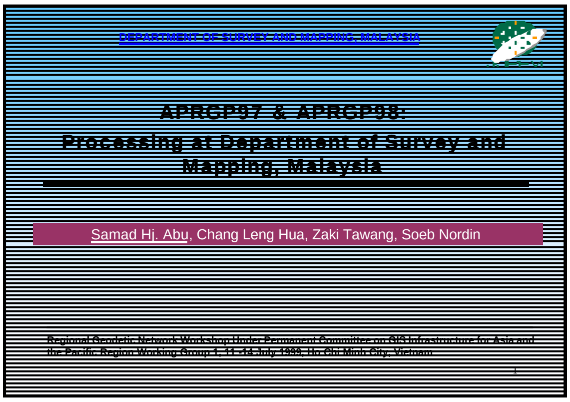
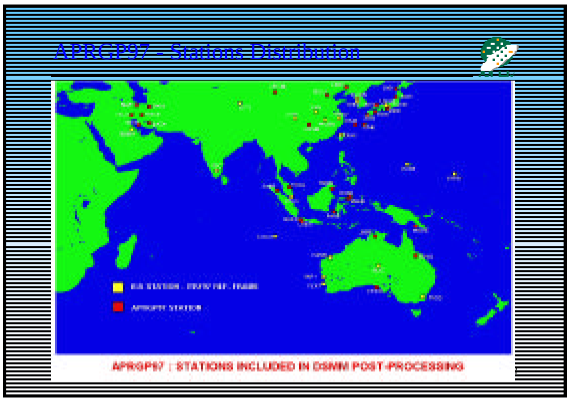
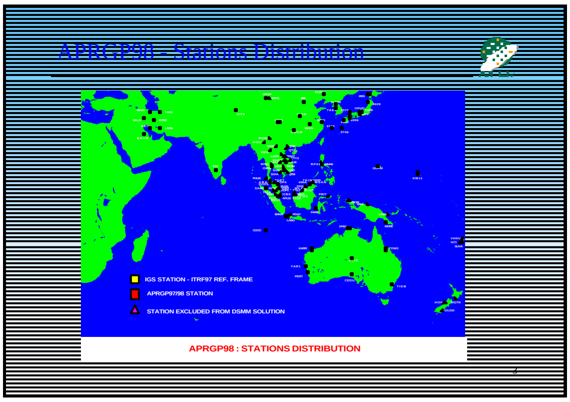
Cecep Subarya

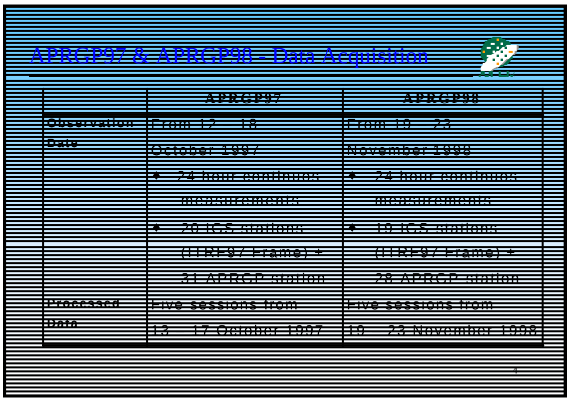
GPS RESULTS FOR APRGP 98

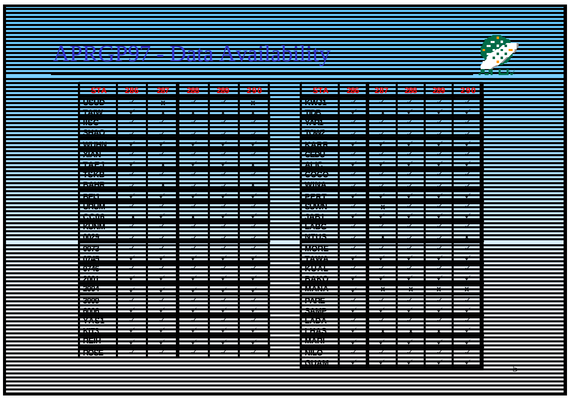
SAMAD ABU/ MALAYSIA

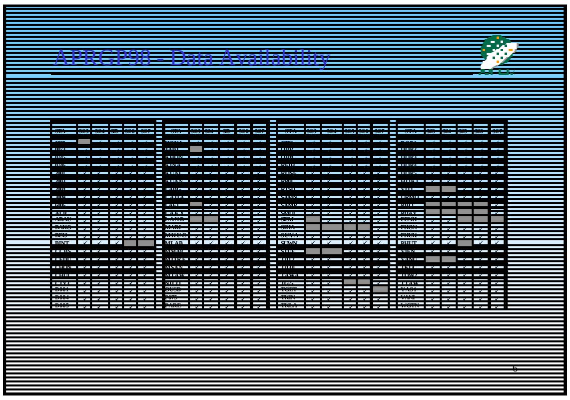


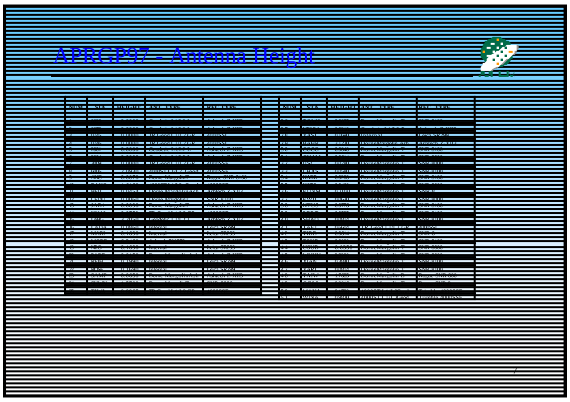


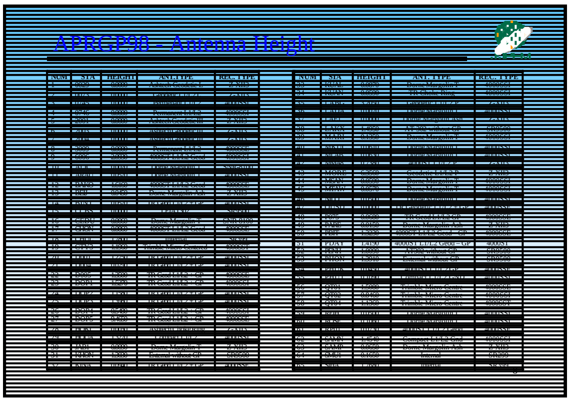


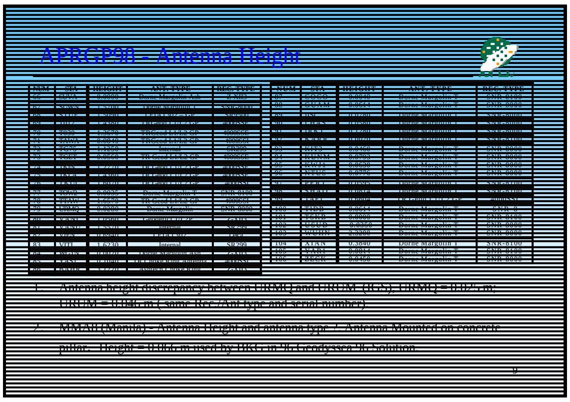


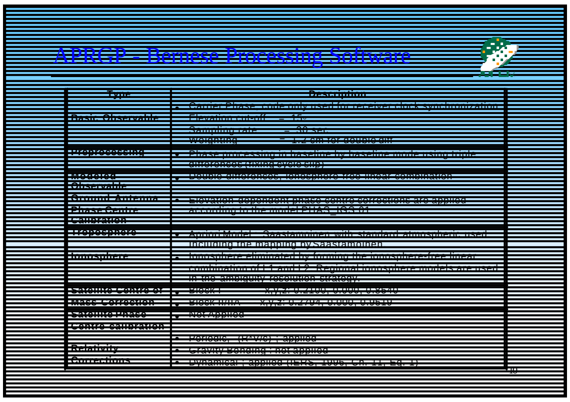


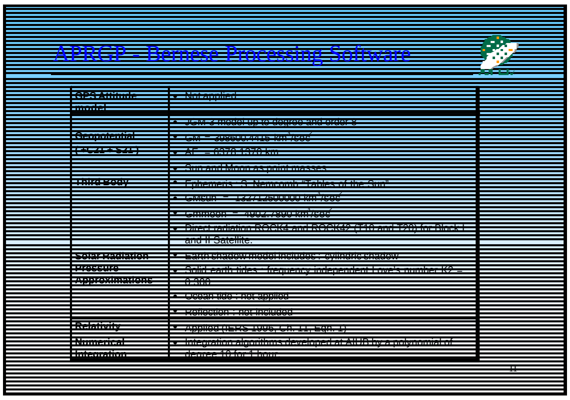


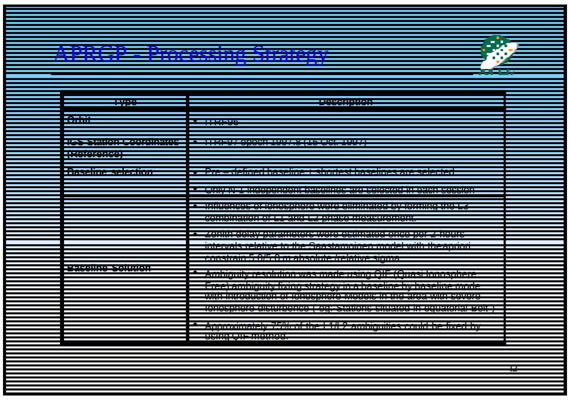

APRGP97 - Antenna Height

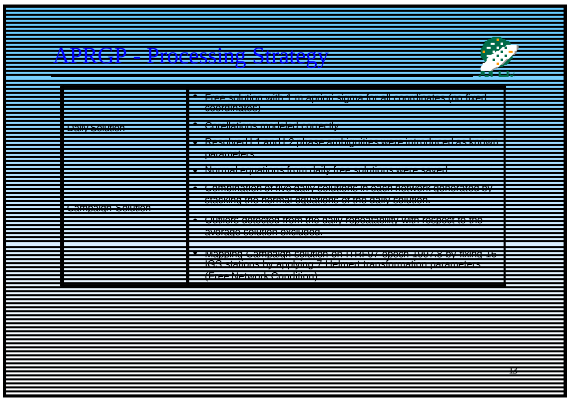

APRGP98 - Antenna Height

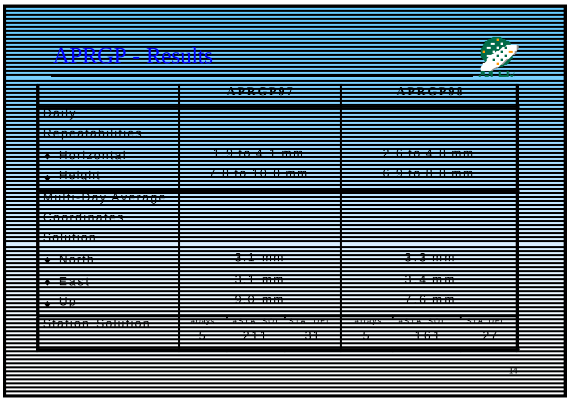

APRGP98 - Antenna Height
1. Antenna height discrepancy between URMQ and URUM (IGS), URMQ = 0.025 m; URUM = 0.046 m (same Rec./Ant type and serial number).
2. MMA98 (Manila) - Antenna Height and antenna type ?. Antenna Mounted on concrete pillar. Height = 0.066 m used by BKG in 96 Geodyssea 96 Solution.
9

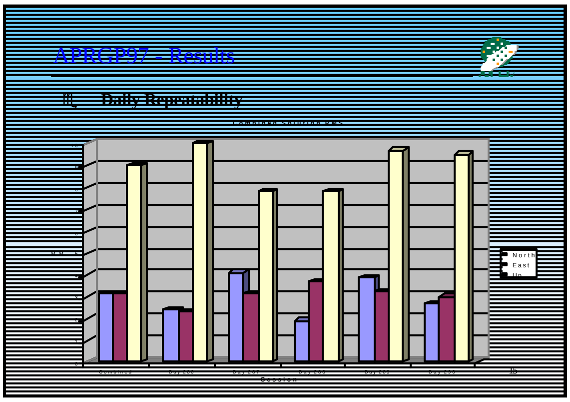

APRGP - Bernese Processing Software
Type
Description
Basic Observable
Carrier Phase, code only used for receiver clock synchronization
Elevation cut-off = 15°
Sampling rate = 30 sec.
Weighting = 1.2 cm for double diff
Preprocessing
Phase processing in baseline by baseline mode using triple differences (fixing cycle slip)
Modeled Observable
Double differences, ionosphere free linear combination
Ground Antenna Phase Centre Calibration
Elevation dependent phase centre corrections are applied according to the model PHAS_IGS.01
Troposphere
Apriori Model : Saastamoinen with standard atmospheric used including the mapping by Saastamoinen
Ionosphere
Ionosphere eliminated by forming the ionosphere-free linear combination of L1 and L2. Regional ionosphere models are used in the ambiguity resolution strategy.
Satellite Centre of Mass Correction
Block I X,Y,Z: 0.2100, 0.000, 0.8540
Block II/IIA X,Y,Z: 0.2794, 0.000, 0.9510
Satellite Phase Centre calibration
Not Applied
Relativity Corrections
Periodic, (R*V/c) ; applied
Gravity Bending ; not applied
Dynamical ; applied (IERS, 1996, Ch. 11, Eq. 1)
10

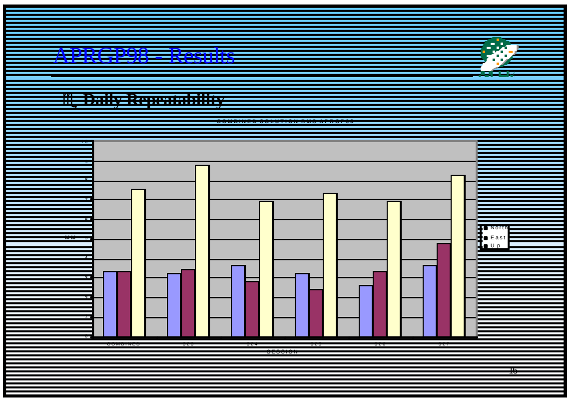

APRGP - Bernese Processing Software
GPS Attitude model
Not applied
Geopotential (+C21 + S21)
JGM-3 model up to degree and order 8
GM = 398600.4415 km3/sec2
AE = 6378.1370 km
Third Body
Sun and Moon as point masses
Ephemeris : S. Newcomb "Tables of the Sun"
GMsun = 132712500000 km3/sec2
Gmmoon = 4902.7890 km3/sec2
Solar Radiation Pressure Approximations
Direct radiation ROCK4 and ROCK42 (T10 and T20) for Block I and II Satellite.
Earth shadow model includes : cylindric shadow
Solid earth tides : frequency independent Love's number K2 = 0.300
Ocean tide : not applied
Reflection : not included
Relativity
Applied (IERS 1996, Ch. 11, Eqn. 1)
Numerical Integration
Integration algorithms developed at AIUB by a polynomial of degree 10 for 1 hour
11

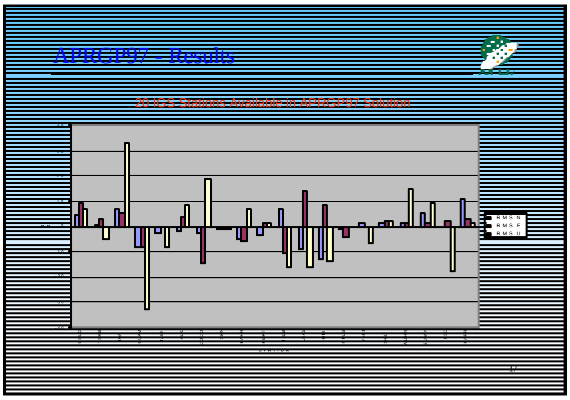

APRGP - Processing Strategy
Type
Description
Orbit
ITRF96
IGS Station Coordinates (Reference)
ITRF97 epoch 1997.8 (15 Oct. 1997)
Baseline selection
Pre – defined baseline ; shortest baselines are selected
Only N-1 independent baselines are selected in each session
Baseline Solution
Influences of ionosphere were eliminated by forming the L3 combination of L1 and L2 phase measurement.
Zenith delay parameters were estimated once per 2 hours intervals relative to the Saastamoinen model with the apriori constrain 5.0/5.0 m absolute /relative sigma
Ambiguity resolution was made using QIF (Quasi Ionosphere Free) ambiguity fixing strategy in a baseline by baseline mode with introduction of Ionosphere Models in the area with severe ionosphere disturbance (eg. Stations situated in equatorial Belt)
Approximately 75% of the L1/L2 ambiguities could be fixed by using QIF method.
12

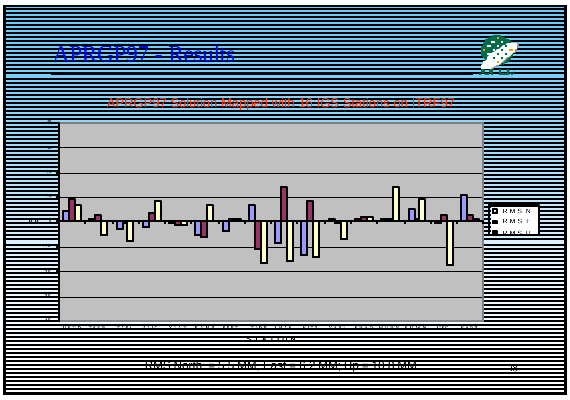

APRGP - Processing Strategy
Daily Solution
Free solution with 1 m apriori sigma for all coordinates (no fixed coordinates)
Corellations modeled correctly
Resolved L1 and L2 phase ambiguities were introduced as known parameters
Normal equations from daily free solutions were saved
Campaign Solution
Combination of five daily solutions in each network generated by stacking the normal equations of the daily solution.
Outliers detected from the daily repeatability with respect to the average solution excluded.
Mapping Campaign solution on ITRF97 epoch 1997.8 by fixing 16 IGS stations by applying 7 Helmert transformation parameters (Free Network Condition).
13

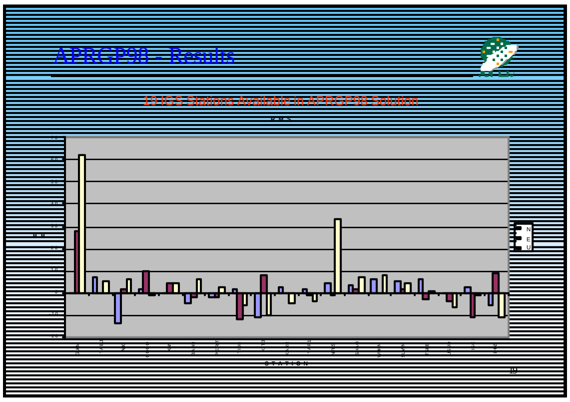

APRGP - Results
APRGP97
APRGP98
Daily Repeatabilities
Horizontal
1.9 to 4.1 mm
2.6 to 4.8 mm
Height
7.8 to 10.0 mm
6.9 to 8.8 mm
Multi-Day Average Coordinates Solution
North
3.1 mm
3.3 mm
East
3.1 mm
3.4 mm
Up
9.0 mm
7.6 mm
Station Solution
5
211
31
5
161
27
14

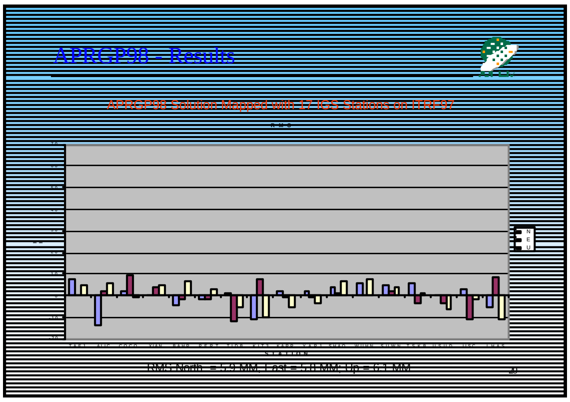

APRGP97 - Results
Daily Repeatability
North
East

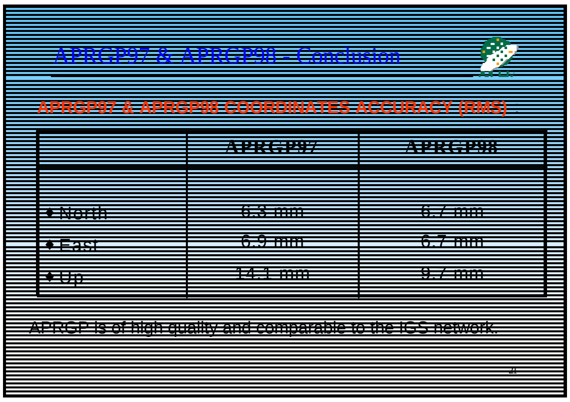

APRGP98 - Results
Daily Repeatability

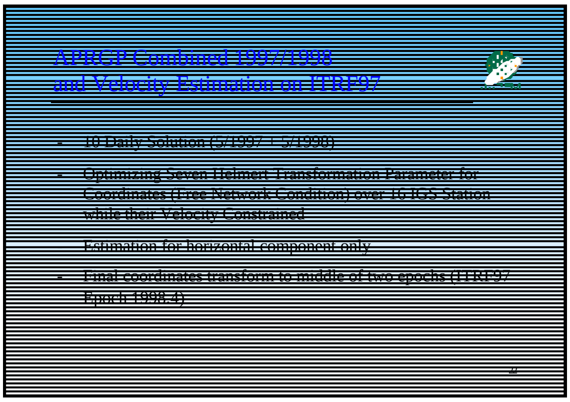

APRGP97 - Results
20 IGS Stations Available in APRGP97 Solution
RMS N
RMS E
RMS U

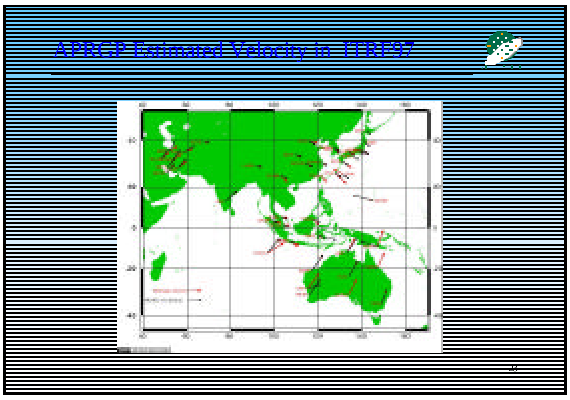

APRGP97 - Results
APRGP97 Solution Mapped with 16 IGS Stations on ITRF97
RMS N
RMS E
STATION
RMS North = 5.5 MM; East = 6.2 MM; Up = 10.8 MM

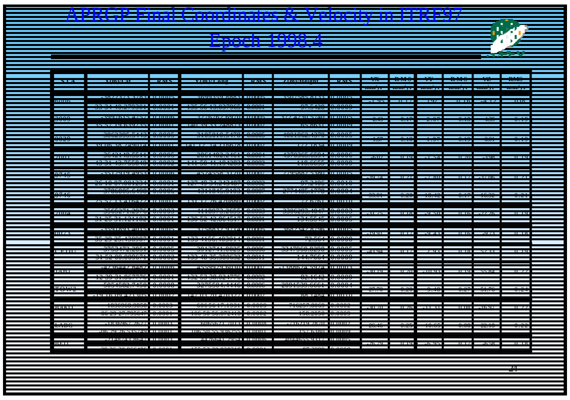

APRGP98 - Results
19 IGS Stations Available in APRGP98 Solution
N
E
U


APRGP98 - Results
APRGP98 Solution Mapped with 17 IGS Stations on ITRF97
N
E
U
RMS North = 5.9 MM; East = 5.8 MM; Up = 6.1 MM


APRGP97 & APRGP98 - Conclusion
APRGP97 & APRGP98 COORDINATES ACCURACY (RMS)
APRGP97
APRGP98
• North
6.8 mm
6.7 mm
• East
6.9 mm
6.7 mm
• Up
14.1 mm
9.7 mm
APRGP is of high quality and comparable to the IGS network.


APRGP Combined 1997/1998
and Velocity Estimation on ITRF97
- 10 Daily Solution (5/1997 + 5/1998)
- Optimizing Seven Helmert Transformation Parameter for Coordinates (Free Network Condition) over 16 IGS Station while their Velocity Constrained
Estimation for horizontal component only
- Final coordinates transform to middle of two epochs (ITRF97 Epoch 1998.4)


APRGP Estimated Velocity in ITRF97


APRGP Final Coordinates & Velocity in ITRF97
Epoch 1998.4

APRGP Final Coordinates & Velocity in ITRF97 Epoch 1998.4

STA	X(m)/Lat	RMS	Y(m)/Long	RMS	Z(m)/Height	RMS	VX mm/yr	RMS mm/yr	VY mm/yr	RMS mm/yr	VZ mm/yr	RMS mm/yr
REIH	3509963.7380	0.0005	4347105.4576	0.0007	3066022.1353	0.0005	-34.08	0.28	6.0	0.23	30.28	0.21
	20 55 00.309562	0.0002	51 04 54.154017	0.0003	54.4144	0.0009						
PARE	-3147782.6402	0.0004	5529856.8024	0.0007	-435535.5703	0.0002	16.44	0.23	9.09	0.13	6.64	0.21
	03 58 41.061397	0.0001	119 39 00.015600	0.0002	134.3422	0.0009						
YAS1	2726445.1473	0.0004	4442016.4981	0.0007	3665092.3185	0.0005	29.57	0.31	10.51	0.22	9.19	0.20
	35 17 33.626384	0.0002	58 27 48.968905	0.0002	1168.2163	0.0009						
KUNM	1281255.5109	0.0003	5640746.0831	0.0010	2682880.0726	0.0005	22.95	0.27	5.84	0.13	23.00	0.25
	25 01 46.343084	0.0002	102 47 49.896627	0.0002	1986.2119	0.0012						
KUAL	1443668.1770	0.0003	6184650.1771	0.0009	587309.9481	0.0002	-38.99	0.26	-4.13	0.06	-3.19	0.21
	05 19 08.001318	0.0001	103 08 20.923952	0.0001	55.0047	0.0009						
SAMP	-964464.9950	0.0002	6291997.2743	0.0010	400195.8782	0.0002	-29.90	0.28	-4.10	0.04	-7.61	0.23
	03 37 17.799475	0.0001	98 42 52.982603	0.0002	2.1129	0.0010						
LADA	3151871.9310	0.0006	4654363.3491	0.0008	3005669.2761	0.0005	-31.25	0.41	5.20	0.30	24.55	0.23
	28 17 38.446808	0.0002	55 53 40.825814	0.0003	916.1264	0.0010						
MART	3205584.5490	0.0005	4075347.1261	0.0007	3705084.7617	0.0006	-30.24	0.34	11.53	0.29	13.39	0.23
	35 43 49.276762	0.0002	51 48 43.686060	0.0003	1813.9243	0.0010						
RUSE	3185578.8844	0.0005	4336094.3794	0.0006	3390274.9290	0.0005	-28.41	0.29	8.11	0.23	16.17	0.20
	32 18 46.995299	0.0002	53 49 20.199342	0.0002	1224.1771	0.0009						
MORE	-5288518.3147	0.0009	3409952.7806	0.0006	-1038574.1046	0.0003	-19.57	0.20	-11.07	0.29	62.89	0.29
	09 26 02.762777	0.0002	147 11 12.284854	0.0002	116.6803	0.0011						
NILO	3582731.9634	0.0006	4026235.4922	0.0007	3399695.6683	0.0006	28.71	0.32	7.59	0.29	21.13	0.22
	32 25 03.740925	0.0002	48 20 08.959752	0.0003	175.8198	0.0010						
TAWA	-2984278.9379	0.0005	5617684.1259	0.0010	469695.7504	0.0002	15.60	0.29	6.20	0.15	24.39	0.28

25

Malaysia Network of APRGP Campaign Result ITRF97 Epoch 1998.9

Station	X(m)/ Lat	RMS	Y(m)/Long	RMS	Z(m)/HGT	RMS
ARAU	-1131051.8369	0.0004	6236311.7694	0.0016	711748.1473	0.0003
	6 27 0.570166	0.0002	100 16 47.058736	0.0002	18.1050	0.0016
DOP5	1143197.9890	0.0003	6237895.1824	0.0015	677621.2983	0.0002
	6 08 22.987629	0.0002	100 25 6.575409	0.0002	-10.0692	0.0015
MKUC	-2200986.1894	0.0005	5983667.2375	0.0012	180479.6750	0.0002
	1 37 56.636458	0.0002	110 11 42.327296	0.0002	79.4834	0.0013
BINT	2495021.3241	0.0007	5858701.7465	0.0015	360450.7177	0.0002
	3 15 41.424934	0.0002	113 04 1.969673	0.0002	46.6666	0.0016
D001	-2702793.0969	0.0006	5747549.4852	0.0012	583412.6854	0.0002
	5 17 0.407751	0.0002	115 11 7.154155	0.0002	113.5307	0.0013
T012	-2496815.5229	0.0005	5858477.3355	0.0012	355737.7020	0.0002
	3 13 7.456456	0.0002	113 04 59.318674	0.0002	204.9954	0.0013
DOP1	-1263945.4623	0.0003	6242705.0041	0.0012	334310.4379	0.0002
	3 01 29.096503	0.0002	101 26 44.874963	0.0002	61.0656	0.0012
MSAN	2990750.4405	0.0006	5596238.14860	0.0011	644936.6541	0.0002
	5 50 32.655661	0.0002	118 07 14.100091	0.0002	135.5609	0.0013
KINA	-2765186.8265	0.0006	5700556.7277	0.0012	651770.6947	0.0002
	5 54 16.574979	0.0002	116 02 21.470644	0.0002	51.7557	0.0013
KUAL	1443668.2064	0.0002	6184650.2113	0.0008	587309.9526	0.0002
	5 19 8.001343	0.0001	103 08 20.924629	0.00001	55.0449	0.0009
KUAN	-1469474.2046	0.0003	6192002.5451	0.0012	425675.2077	0.0002
	3 50 3.760717	0.0002	103 21 1.268617	0.0002	25.4833	0.0012
MTAW	-2974552.4929	0.0006	5622306.2204	0.0012	470932.6302	0.0002
	4 15 45.986897	0.0002	117 52 53.929473	0.0002	72.9341	0.0013

Malaysia Network of APRGP Campaign Result ITRF97 Epoch 1998.9

Station	X(m)/ Lat	RMS	Y(m)/Long	RMS	Z(m)/HGT	RMS
TTAW	2974504.0458	0.0006	5622478.7132	0.0012	469819.0790	0.0002
	4 14 43.551072	0.0002	117 52 49.925050	0.0002	50.4435	0.0013
TKLA	1254411.6107	0.0003	6244432.4359	0.0012	336712.3462	0.0002
	3 02 47.509807	0.0002	101 21 31.21234	0.0002	0.5769	0.0012
DOP4	-1353514.2009	0.0004	6196995.6060	0.0014	666524.9939	0.0002
	6 02 19.307253	0.0002	102 19 14.683948	0.0002	107.6495	0.0015
TGET	1329733.1215	0.0004	6199766.6934	0.0015	687129.5533	0.0003
	6 13 34.292175	0.0002	102 06 19.666668	0.0002	-0.4160	0.0016
TKIU	-2224775.5876	0.0005	5975001.1133	0.0013	175039.3401	0.0002
	1 34 59.485471	0.0002	110 25 21.645883	0.0002	37.5020	0.0014
TAWA	-2984278.9575	0.0005	5617684.1365	0.0009	469695.7412	0.0002
	4 15 04.693233	0.0001	117 58 42.793511	0.0001	451.9321	0.0010
D004	2984273.6155	0.0006	5617687.3235	0.0012	469697.2024	0.0002
	4 15 4.739923	0.0002	117 58 42.592057	0.0002	452.3480	0.0013
MLAB	-2708733.1678	0.0007	5744691.0146	0.0014	583321.4215	0.0002
	5 16 57.615802	0.0002	115 14 41.230233	0.0002	49.8347	0.0015
D005	2827033.5932	0.0007	5673603.0028	0.0014	705604.6184	0.0003
	6 23 38.669710	0.0002	116 29 9.897463	0.0002	195.3205	0.0016
TKIN	-2790190.3593	0.0007	5697101.1810	0.0013	660474.5433	0.0002
	5 59 1.447979	0.0002	116 05 36.911704	0.0002	51.6656	0.0015
T030	2203525.8613	0.0006	5982977.8632	0.0015	175363.7970	0.0002
	1 35 9.953868	0.0002	110 13 7.359963	0.0002	147.2556	0.0016
DOP7	1500246.2600	0.0004	6187398.0258	0.0013	152195.8532	0.0002
	1 22 35.481672	0.0002	103 36 29.488209	0.0002	91.6583	0.0013
DOP3	-1391259.0723	0.0003	6212962.5409	0.0013	382801.3245	0.0002
	3 27 49.890626	0.0002	102 37 18.938214	0.0002	269.3069	0.0013

Final combined MALAYSIA'98 Coordinates solutions in the ITFR97 (Epoch 1998.92) Reference Frame
(RMS is the formal accuracy of each component from combined solution, representing the internal precision of the solution)

27

Conclusion and Recommendation

1. Result from both GPS campaign are of high accuracy.
2. Comparison between difference processing centre to check any error (eg. Ant height).

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ASIA-PACIFIC REGIONAL GEODETIC PROJECT 1998. SATELLITE LASER RANGING SOLUIONS.

Ramesh Govind, John Dawson and Geoff Luton
Australian Surveying and Land Information Group Canberra Australia.

1. Data:

Figure 1 shows the global distribution of SLR stations.

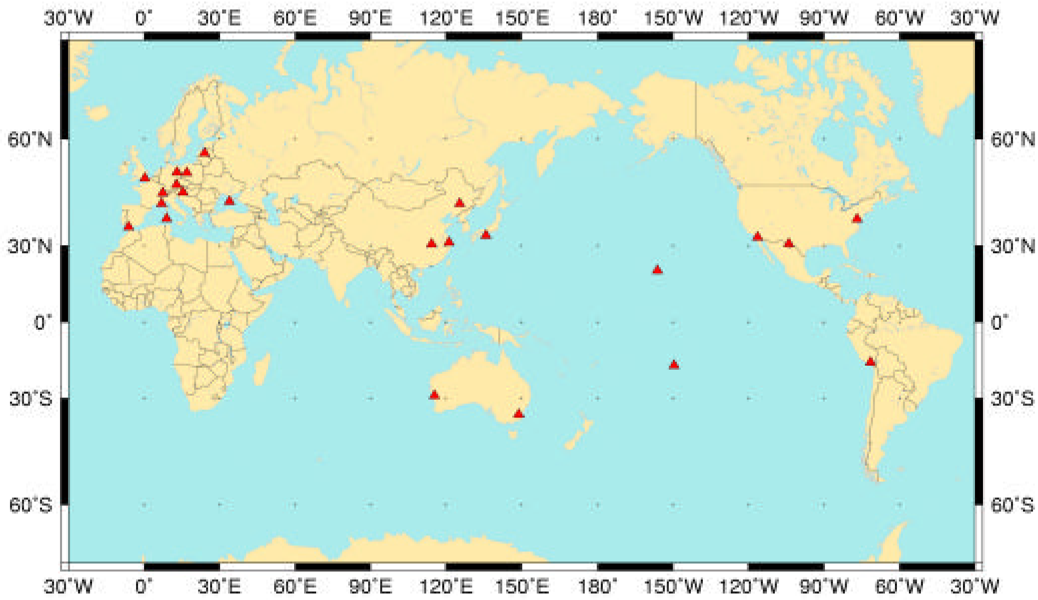

Figure 1: Distribution of SLR observing stations during APRGP98.

Table 1 gives the Geodetic SLR satellites generally tracked, size of the satellite, orbit parameters, approximate period for one revolution, typical duration of a single pass over a station and normal point data intervals.

Table 1: SLR "cannonball" satellites observed during the APRGP98.

Satellite	Semi Major Axis (Km)	Eccentricity	Inclination. (deg)	Diameter (cm)	Orbit Period (hrs:min)	Pass Duration (mins)	NP Interval
Lageos-1	12250	.0045	109	50	3:50	25	2 min
Lageos-2	12160	.0013	52.5	50	3:50	25	2 min
Stella	7170	.0011	98.5	15	1:40	5-6	30 sec
Starlette	7330	.0200	50	15	1:40	6-10	30 sec
Ajisai	7865	.0020	50	220	1:55		30 sec
Etalon-1	25500	.0009	65	111	11:15		5 min
Etalon-2	25500	.0007	65	111	11:15		5 min

The current APRGP98 solution comprises only of data for the Lageos-1 and Lageos-2 satellites.

2. SLR Computation Procedure / Computation Standards

The AUSLIG data processing procedure is the full implementation of the IERS Conventions 1996 (McCarthy, 1996).

Measurement Modelling

TROPOSPHERE	Marini and Murray troposhere model for optical frequencies

Orbit Modelling

Earth's Gravitational (Static) Potential Model	JGM-3 – degree and order 70
Solid Earth Tides (Dynamic) Potential	Love Model
Ocean Tide (Dynamic) Potential	Christodoulidis
Third Body Perturbations	Sun, Moon and Planets Values for physical constants – AU, Moon/Earth mass ratio, GM (moon, sun and planets) from JPL DE403 Planetary Ephemeris.
Direct Solar Radiation Pressure	Cannonball
Centre of Mass Correction / Attitude	Observation Correction applied

Station Position Modelling / Reference Frame

Precession	IAU76/IERS96
Nutation	IAU80/IERS96 (including epsilon and psi corrections)
Sine terms added to accumulated precession and nutation in Right Ascension	As in IERS TN 21, p. 21
Geodesic Nutation	As in IERS TN 21, p.37
Polar Motion	Bulletin B – apriori
Earth Rotation (UT1)	Bulletin B – apriori
Daily and Sub-daily tidal corrections to X,Y and UT1	Applied
Plate Motion	CSR96L01/ITRF96/97
Planetary and Lunar Ephemeris	JPL DE403
Station Displacement – Solid earth Tide Loading	Williamson and Diamante (1972) + Wahr (1980) for the frequency dependent elastic response of the Earth's fluid interior
Station Displacement – Ocean Tide Loading	Scherneck (1991)
Station Displacement – Pole Tide	Applied as a default
Station Displacement – Atmospheric Loading	NIL
Reference Frame –	AUSLIG Hybrid (CSR96l01/ITRF)

Estimated Parameters:
For a one-month arc, the following global and arc parameters were estimated.

Global:
- Station Coordinates
- Daily UT [A1-UT1] and pole.

Arc Parameters:
- State vector for all satellites
- One Solar Radiation Pressure scale factor
- One Drag parameter per day [for Stella, Starlette].
- General Acceleration estimated once per five day – constant, once per revolution sine and cosine of the period in the along track and cross track direction.
- Measurement range bias – pass by pass
- Measurement time bias – pass by pass

Results

Table 2 gives the weighted RMS-of-fit per satellite per station (mm) for the individual 30-day arc satellite solutions.

Table 2: Lageos-1 and Lageos-2 Residual Summary by stations for November 1998.

Lag-1 No. NP	Lag-2 No. NP	LAG-1 RMS (mm)	LAG-2 RMS (mm)	STATION
353	348	2.6	3.9	MONU7110
514	243	3.1	4.6	HERS7840
471	271	2.9	5.9	GRAZ7839
335	134	2.0	3.5	GREE7105
583	330	2.8	3.3	YARR7090
114	73	2.7	4.8	HALE7210
44	7	4.8	7.6	POTS7836
255	280	3.7	3.8	MCDO7080
179	31	3.1	6.2	STRM7849
30	50	5.8	6.8	SHAN7837
51	58	5.8	8.0	CHAN7237
31		6.6		BORO7811
135	117	6.2	6.4	ZIMM7810
161	65	3.4	4.6	GRAS7845
25		4.3		SANF7824
13	51	7.0	8.3	WETT8834
82	94	2.8	3.6	KOGA7328
57	26	4.1	4.1	MIUR7337
76		5.5		RIGA1884
7		6.9		CAGF7548
71	35	6.5	9.6	SIMO7838
27	6	3.2	2.6	TAHI7124
93	73	2.3	2.7	TATE7339
8	5	3.3	3.0	KASH7335
37		2.4		GRAS7835
12		5.8		METS7806
	11		8.3	HELW7831

RMS of fit for 3786 normal point observations to lageos-1 over a 1-month arc is 4 mm and the RMS of fit for 2308 normal point observations to lageos-2 over a 1-month arc is 5 mm. Table 3 gives the estimated set of seven transformation parameters between the AUSLIG solution and the ITRF96.

Table 3 Seven-parameter transformation of AUSLIG SLR solution onto ITRF96.

Scale	T1	T2	T3
1.00 ppb	0.50 mm	-4.50 mm	-12.6 mm
	R1	**R2**	**R3**
	0.04 mas	-0.08 mas	0.06 mas
	X RMS	**Y RMS**	**Z RMS**
	15.9 mm	17.5 mm	13.4 mm
	East RMS	**North RMS**	**Up RMS**
	20.4 mm	8.7 mm	15.7 mm
	3D RMS	**Degrees of Freedom**	
	15.7 mm	38	

Table 4 gives the differences between the estimated transformed AUSLIG coordinates compared to ITRF96. This is indicative of the accuracy of the solution in each component. Hale, Stromlo, Changchun and the Keystone stations were not included in the estimation for the transformation parameters. The final coordinates for these stations are given in appendix A.

Table 4: Difference between ITRF96 and AUSLIG SLR after 7 parameter transformation.

SATION	ID	DOMES	dX(mm)	dY(mm)	dZ(mm)	dE(mm)	dN(mm)	dU(mm)
RIGA	1884	12302S002						
MCDO	7080	40442M006						
YARR	7090	50107M001						
GREE	7105	40451M105						
MONU	7110	40497M001						
ZIMM	7810	14001S001						
BORO	7811	12205S001						
HELW	7831	30101S001						
GRAS	7835	10002S001						
POTS	7836	14106S009						
SHAN	7837	21605S001						
SIMO	7838	21726S001						
GRAZ	7839	11001S002						
HERS	7840	13212S001						
WETT	8834	14201S018						
		RMS						

Summary of Results:

This one-month SLR solution using Lageos-1 and Lageos-2 data forms part of a one-year solution submitted to the IERS Continuous Time Series Pilot project. The solution fits the ITRF96 set of station coordinates at the 16 mm level. However, eccentricity information still needs further investigation. The differences in the coordinates for Changchun with the ITRF96 values is due to errors in the ITRF96 velocity for Changchun. The CRL Keystone stations have also been included in the network – giving good results overall. However, there needs to be an increase in WPLTN data output to Lageos-1 and Lageos-2. The final estimated coordinates for the participating stations are listed in Appendix A.

APPENDIX A

ITRF96 coordinates at 1998.87 for APRGP98 SLR Observing Stations.

STATION	ITRF96-X	ITRF96-Y	ITRF96-Z
RIGA1884	3183895.949	1421497.052	5322803.753
MCDO7080	-1330021.056	-5328401.878	3236480.758
YARA7090	-2389006.941	5043329.329	-3078524.858
GREE7105	1130719.639	-4831350.598	3994106.534
MONU7110	-2386278.240	-4802354.113	3444881.609
TAHI7124	-5246406.703	-3077284.931	-1913814.154
HALE7210	-5466006.633	-2404427.307	2242187.796
CHAN7237	-2674386.740	3757189.327	4391508.346
KOGA7328	-3941941.212	3368169.619	3702195.633
KASH7335	-3997484.270	3276846.837	3724296.581
MUIR7337	-3976161.640	3377950.391	3656687.281
TATE7339	-4000955.169	3375310.489	3632200.831
CAGL7548	4893347.302	772582.989	4004255.210
METS7806	2892607.101	1311813.210	5512598.712
ZIMM7810	4331283.528	567549.754	4633140.130
BORO7811	3738332.844	1148246.505	5021816.023
SANF7824	5105473.769	-555110.840	3769892.439
HELW7831	4728283.391	2879670.394	3156894.741
GRAS7835	4581691.673	556159.553	4389359.494
POTS7836	3800639.693	881982.057	5028831.682
SHAN7837	-2831088.107	4676203.314	3275172.743
SIMO7838	-3822388.312	3699363.565	3507573.072
GRAZ7839	4194426.533	1162694.049	4647246.646
HERS7840	4033463.735	23662.493	4924305.176
GRAS7845	4581692.239	556196.048	4389355.083
STRM7849	-4467063.650	2683034.435	-3667007.323
WETT8834	4075576.869	931785.471	4801583.556

ASIA-PACIFIC REGIONAL GEODETIC PROJECT 1998.
Doppler Orbitography Range Integrated by Satellite (DORIS) Solutions.

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Introduction:

DORIS was developed as an efficient system for Precise Orbit Determination of Low Orbiting Satellites. However, it has proved to be a significant tool for high precision global geodesy. DORIS is on the following satellites:

TOPEX/Poseidon	Altimetry
SPOT-2	Remote Sensing
SPOT-3	Remote Sensing
SPOT-4	Remote Sensing

In future the Jason and Envirsat satellites will also be equipped with DORIS receivers. This demonstrates the contribution of radio navigation system on a remote sensing satellites to global geodesy.

For the APRGP98 campaign, DORIS data from the SPOT-2 satellite was processed.

The general orbit parameters for SPOT-2 (and SPOT-3) are:

Semi Major Axis	Altitude	Eccentricity	Inclination	Period
7200 Kms	822 Kms	0	98 degrees	101 mins.
Repeat Cycle	Rev/cycle			
26 days	369			

Data:

Figure 1 shows the global distribution of DORIS stations – approximately 50.

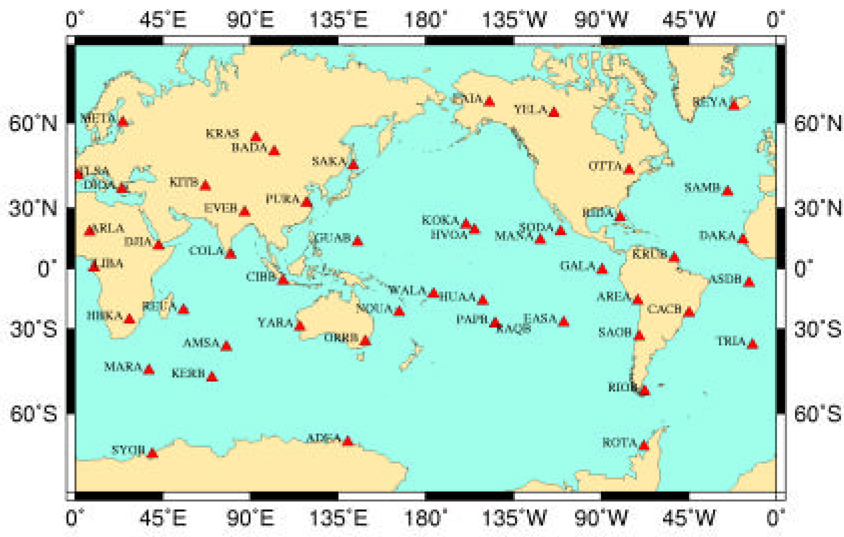

Figure 1: Global Distribution of DORIS network of beacons.

DORIS Computation Standards

The AUSLIG data processing procedure is a full implementation of the IERS Conventions 1996 (McCarthy, 1996).

Measurement Modelling

OBSERVABLES	Range Rate and Integrated Doppler Count (Doppler Count Interval app. 10 secs)
TROPOSPHERE	Tropospheric delay is part of the observation file in the form of range rate corrections. –These can be from several sources
IONOSPHERE	DORIS ground beacons transmit at 400 MHz and 2 GHz frequencies. Ionosphere corrections in the form of range-rate corrections are part of the distributed data file.
Satellite Centre of Mass Offset and Ground Antenna phase offset	Accounted for in the observed data.

Orbit Modelling

Earth's Gravitational (Static) Potential Model	JGM-3 – degree and order 70
Solid Earth Tides (Dynamic) Potential	Love Model
Ocean Tide (Dynamic) Potential	Christodoulidis
Third Body Perturbations	Sun, Moon and Planets Values for physical constants – AU,

	Moon/Earth mass ratio, GM (moon, sun and planets) from JPL DE403 Planetary Ephemeris.
Direct Solar Radiation Pressure	Cannonball
Atmospheric Drag	Jachhia Model
Centre of Mass Correction / Attitude	Correction for ground transmitting antenna phase centre and the satellite antennae centre of mass correction is supplied with the data as a range rate correction.

Station Position Modelling / Reference Frame

Precession	IAU76/IERS96
Nutation	IAU80/IERS96 (including epsilon and psi corrections
Sine terms added to accumulated precession and nutation in Right Ascension	As in IERS TN 21, p. 21
Geodesic Nutation	As in IERS TN 21, p.37
Polar Motion	Bulletin B – apriori
Earth Rotation (UT1)	Bulletin B – apriori
Daily and Sub-daily tidal corrections to X,Y and UT1	Applied
Plate Motion	ITRF97 velocities
Planetary and Lunar Ephemeris	JPL DE403
Station Displacement – Solid earth Tide Loading	Williamson and Diamante (1972) + Wahr (1980) for the frequency dependent elastic response of the Earth's fluid interior
Station Displacement – Ocean Tide Loading	Scherneck (1991)
Station Displacement – Pole Tide	Applied as a default
Station Displacement – Atmospheric Loading	NIL
Reference Frame –	ITRF97 positions and velocities

Estimated Parameters:

The one-month data set was computed in 5-day arcs. The following global and arc parameters were estimated per 5-day arc. The five 5-day arcs were later combined at the normal equation level into a single one-month solution.

Global:

- Station Coordinates
- Daily UT1 and pole position.

Arc Parameters

- State vector for SPOT-2 (five-day arcs)
- One Solar Radiation Pressure scale factor
- Three Drag parameter per day.
- General Acceleration estimated once per day – constant, once per revolution sine and cosine of the period in the along track and cross track direction.

- Measurement range-rate bias – pass by pass
- Measurement time bias – pass by pass

Results

The weighted rms-of-fit per satellite per station for the individual five-day solutions were at the 0.6 mm/sec. Station coordinate repeatability per five day solution is between 1.0 and 3.0 cm. Table 1 gives the set of seven transformation parameters for the one-month AUSLIG DORIS solution compared to the ITRF97. Table 2 lists the coordinate differences between the transformed AUSLIG solution compared to ITRF97. This gives an indication of the accuracy of the solution in each component. Appendix A lists the estimated coordinates for the DORIS stations in ITRF97.

Table 1: Seven parameter transformation of AUSLIG DORIS solution onto ITRF96.

Scale	T1	T2	T3
-0.52 ppb	0.9 mm	-0.5 mm	0.6 mm
	R1	**R2**	**R3**
	0.00 mas	-0.02 mas	0.00 mas
	X RMS	**Y RMS**	**Z RMS**
	16.9 mm	12.1 mm	17.1 mm
	East RMS	**North RMS**	**Up RMS**
	10.8 mm	17.0 mm	17.8 mm
	3D RMS	**Degrees of Freedom**	
	15.5 mm	95	

Table 2: Difference between ITRF97 and AUSLIG DORIS after 7 parameter transformation.

	ID	DOMES	dX(mm)	dY(mm)	dZ(mm)	dE(mm)	dN(mm)	dU(mm)
1	ADEA	91501S001	-17.1	4.3	15.4	7.7	20.7	-7.8
2	AREA	42202S005	-0.5	-2.2	-1.2	-1.2	-0.6	2.2
3	ARMA	33710S002	-20.4	6.6	-33.0	9.1	-25.0	-29.0
4	BADA	12338S001	-1.7	-4.7	-10.4	2.7	-3.1	-10.8
5	CIBB	23101S001	21.3	-15.1	-14.4	-16.0	-16.6	-18.8
6	COLA	23501S001	-13.5	-23.2	23.1	9.2	25.9	-22.2
7	DAKA	34101S004	-37.8	21.5	11.7	9.2	22.2	-38.1
8	DIOA	12602S011	-7.6	16.5	-11.6	18.1	-9.0	-7.3
9	DJIA	39901S002	-9.9	-24.0	-23.2	-10.9	-18.0	-27.8
10	EASA	41703S008	-1.4	-0.4	-0.7	-1.2	-0.2	1.0
11	EVEB	21501S001	11.1	-35.9	8.6	-13.1	24.1	-27.1
12	FAIA	40408S004	0.0	1.1	3.7	-0.9	2.1	3.0
13	GOMB	40405S037	-1.3	1.9	2.6	-2.0	2.8	0.5
14	GUAB	50501S001	-2.3	-1.1	-1.6	2.2	-1.9	0.8
15	KERB	91201S003	-0.2	5.9	-0.6	2.1	3.7	4.0
16	KITB	12334S005	-0.1	3.8	0.6	1.6	-1.7	3.1
17	KOKA	40424S008	-1.6	1.4	1.8	-1.9	1.3	1.6
18	KRUB	97301S004	-1.3	5.7	-0.4	2.4	0.1	-5.4
19	LIBA	32809S002	-32.9	16.1	-7.5	21.4	-7.3	-29.8
20	MANA	22006S001	8.4	-22.6	-6.2	4.5	0.0	-24.5
21	META	10503S013	1.8	3.7	-0.3	2.7	-2.9	1.4
22	NOUA	92701S001	4.4	-5.5	-5.8	4.3	-7.5	-2.9
23	PURA	21604S003	42.7	-5.8	-15.1	-34.6	0.8	-29.7
24	REUA	97401S001	6.3	-7.4	22.1	-9.4	19.7	-10.3
25	RIDA	40499S016	-0.7	-2.2	-2.3	-1.1	-3.0	0.8
26	RIOB	41507S004	0.9	-3.9	5.1	-0.7	6.2	-1.8
27	ROTA	66007S001	28.7	-3.0	36.9	25.5	26.5	-28.9
28	SAKA	12329S001	30.0	-9.5	-37.7	-10.6	-4.0	-47.8
29	SAOB	41705S008	-0.5	-1.8	-2.6	-1.1	-1.3	2.7
30	SPIA	10317S002	2.6	-6.2	-4.4	-6.6	-2.0	-4.1
31	TRIA	30604S001	37.2	-18.7	49.4	-10.3	63.8	2.4
32	WALA	92901S001	21.2	-5.8	-26.1	7.2	-30.2	-14.3
33	YARA	50107S006	-2.1	1.6	-0.9	1.2	0.3	2.5
34	YELA	40127S007	0.0	0.2	0.1	0.0	0.2	0.0
		RMS	16.9	12.1	17.1	10.8	17.0	17.8

Summary of Results:

- The solution fits the ITRF97 at the 15 mm level – a good result. The total rms when fitted to ITRF97 are 11, 17 and 18 mm for the East, North and Up components respectively. DORIS is a promising high precision space geodetic technique in remote regions for the densification of the ITRF at the cm level.

APPENDIX A

ITRF97 coordinates at 1998.87 for APRGP98 DORIS Observing Stations.

STATION	ITRF97-X	ITRF97-Y	ITRF97-Z
SPIA	1202793.963	254163.097	6237609.313
META	2890641.115	1310310.574	5513964.929
SAKA	-3465326.211	2638266.690	4644082.318
KITB	1945024.358	4556708.343	4004235.353
BADA	-838277.787	3865776.988	4987626.659
DIOA	4595215.267	2039475.454	3912615.005
EVEB	313666.348	5633552.664	2974736.794
PURA	-2608502.065	4739980.347	3366883.034
MANA	-3184357.521	5291042.203	1590419.405
CIBB	-1836963.595	6065626.697	-716217.323
COLA	1113278.403	6233646.296	760276.764
HBLA	5084641.463	2670350.061	-2768497.876
TRIA	4978463.281	-1086620.692	-3823205.504
LIBA	6287388.607	1071574.293	39147.211
ARMA	5991269.328	773728.606	2040688.569
DAKA	5886437.435	-1848461.510	1611441.820
DJIA	4583119.433	4250952.218	1266247.681
YELA	-1224424.078	-2689227.453	5633645.230
GOMB	-2350858.662	-4655545.761	3661004.743
KOKA	-5543974.650	-2054589.795	2387488.202
RIDA	960756.801	-5673685.123	2741529.521
RIOB	1429854.178	-3495342.362	-5122725.201
EASA	-1884993.601	-5357605.057	-2892858.712
SAOB	1769700.369	-5044614.905	-3468261.230
GALA	42716.776	-6377216.495	-99590.665
AREA	1942796.774	-5804077.725	-1796919.090
YARA	-2389004.011	5043340.617	-3078512.992
GUAB	-5075278.474	3565110.794	1483590.911
ROTA	909378.230	-2264934.540	-5872956.915
KERB	1405826.408	3918281.821	-4816204.314
ADEA	-1941059.607	1628659.307	-5833613.537
NOUA	-5739993.762	1387548.336	-2402085.228
WALA	-6195393.737	-413727.778	-1454075.294
KRUB	3855261.256	-5049734.815	563057.803
REUA	3364093.831	4907945.479	-2293482.330