Data Analysis for Determination of International Terrestrial Reference Frame (ITRF) Coordinates for the August 2007 Southern Fiji Islands GPS Survey Campaign Network

GEOSCIENCE AUSTRALIA
RECORD 2008/04

by

G. Luton [1], G. Hu[1].

Australian Government
Geoscience Australia

1. National Geospatial Reference Systems Project, Geospatial & Earth Monitoring Division, c/- Geoscience Australia GPO Box 378 Canberra ACT 2601

Department of Resources, Energy and Tourism
Minister for Resources, Energy and Tourism: The Hon. Martin Ferguson, MP
Secretary: Dr. Peter Boxall

Geoscience Australia
Chief Executive Officer: Dr Neil Williams

ISSN 1448-2177
ISBN 978-1-921236-77-8

GeoCat # 65650

Bibliographic reference: Luton, G. and Hu, G., 2008. Data Analysis for Determination of International Terrestrial Reference Frame (ITRF) Coordinates for the August 2007 Southern Fiji Islands GPS Survey Campaign Network. Geoscience Australia, Record 2008/04. 11pp.

Contents

Executive Summary

DATA ANALYSIS FOR DETERMINATION OF INTERNATIONAL TERRESTRIAL REFERENCE FRAME (ITRF) COORDINATES FOR THE AUGUST 2007 SOUTHERN FIJI ISLANDS GPS SURVEY CAMPAIGN NETWORK

The Pacific Islands Applied Geoscience Commission (SOPAC) requested Geoscience Australia to compute International Terrestrial Reference Frame (ITRF) coordinates for 9 survey sites on islands in the southern Fiji archipelago from continuous geodetic GPS measurements observed from 4th to 11th August 2007 inclusive. The GPS data was processed using version 5.0 of the Bernese GPS Software in a regional network together with selected IGS sites. The GPS solution was constrained to the ITRF2005 reference frame through adopting IGS05 coordinates on selected IGS reference sites and using the final IGS earth orientation parameters and satellite ephemerides products.

These coordinates provide the coordinate reference frame to be used to define Fiji's claim to extended continental shelf under the provisions of Article 76 of the United Nations Convention on the Law of the Sea.

Introduction

This report documents the data processing and analysis of the 2007 Southern Fiji Islands 8-day GPS survey campaign from 4th to 11th August inclusive (days of year 216 to 223). The data set of the campaign is described first. Then the data processing scheme is detailed, followed by the results of processing including the final computed station coordinates and the repeatability RMS (root mean square) of these coordinates. Finally a set of transformation parameters was determined to enable transformation of existing Fiji WGS72 geodetic datum coordinates into the new coordinate system.

GPS Data Set

The GPS data set was provided by the Secretariat of the Pacific Islands Applied Geoscience Commission (SOPAC) in RINEX format for nine stations within the Southern Fiji Islands. Figure 1 shows the relative positions of these stations. Each station was equipped with one Leica GPS antenna and dual frequency GPS receiver. Table 1 summarises the receivers, antennas and antenna heights for the GPS data set, which used a 30-second sampling interval.

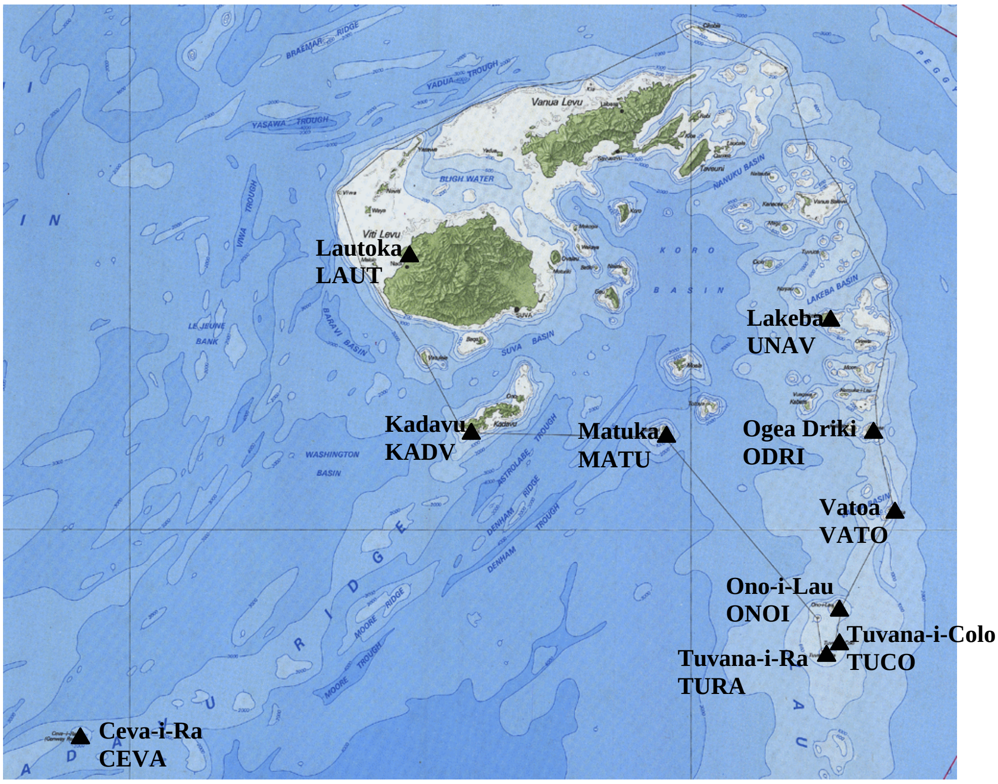

Figure 1: *The distribution of the nine stations of the 2007 Southern Fiji Islands GPS campaign.*

Table 1. GPS receivers and antennas used for the stations of the Fiji 2007 campaign.

SITE	4-char. ID	RECEIVER TYPE	ANTENNA TYPE	ANTENNA DOME TYPE	ANTENNA HEIGHT TO ARP (m)
Ceva-i-Ra	CEVA	LEICA GX1230	LEIAX1202	NONE	1.6330
Kadavu	KADV	LEICA GX1230	LEIAX1202	NONE	1.7530
Matuku	MATU	LEICA GX1230	LEIAX1202	NONE	1.6000
Ogea Driki	ODRI	LEICA SR520	LEIAT502	NONE	1.4600
Ono-i-Lau	ONOI	LEICA GX1230	LEIAX1202	NONE	1.6890[b]
Tuvana-i-Colo	TUCO	LEICA GX1230	LEIAX1202[a]	NONE	1.4990
Tuvana-i-Ra	TURA	LEICA SR520	LEIAT502	NONE	1.7940
Lakeba	UNAV	LEICA GX1230	LEIAX1202[a]	NONE	1.6550
Vatoa	VATO	LEICA SR520	LEIAT502	NONE	1.6760

*Note **a**. Antenna type adopted from GPS Survey Log sheet. LEIAT502 incorrectly listed in RINEX file header record.*

*Note **b**. Antenna height adopted from RINEX file header record. Antenna height information listed in GPS Survey Log sheet may be in error. This information verbally provided by SOPAC.*

Table 2. GPS receivers and antennas for other stations included in the data analysis.

SITE	RECEIVER TYPE	ANTENNA TYPE	ANTENNA DOME TYPE	ANTENNA HEIGHT TO ARP (m)
ASPA	TRIMBLE 4700	TRM33429.20+GP	UNAV	0.0000
AUCK	TRIMBLE NETRS	TRM41249.00	NONE	0.0550
CHAT	ASHTECH Z-XII3	ASH701945C_M	NONE	0.0062
CKIS	ASHTECH UZ-12	ASH701945C_M	SCIS	0.0000
DARW	ASHTECH UZ-12	ASH700936D_M	NONE	0.0025
FALE	ASHTECH Z-XII3	ASH701945E_M	SNOW	0.0000
HOB2	ASHTECH UZ-12	AOAD/M_T	NONE	0.0000
KIRI	ASHTECH UZ-12	ASH701945C_M	SCIS	0.0000
KOUC	TRIMBLE NETRS	TRM41249.00	TZGD	0.0000
LAUT	ASHTECH UZ-12	ASH701945C_M	SCIS	0.0000
MAJU	ASHTECH UZ-12	ASH701945C_M	SCIS	0.0000
NAUR	ASHTECH UZ-12	ASH701945C_M	SCIS	0.0000
PNGM	ASHTECH UZ-12	ASH701945C_M	SCIS	0.0000
POHN	ASHTECH UZ-12	ASH701945C_M	SCIS	0.0000
SAMO	ASHTECH UZ-12	ASH701945C_M	SCIS	0.0000
SUNM	JPS LEGACY	JPSREGANT_SD_E	NONE	0.0770
TIDB	ASHTECH Z-XII3	AOAD/M_T	JPLA	0.0614
TONG	ASHTECH UZ-12	ASH701945C_M	SCIS	0.0000
TOW2	ASHTECH UZ-12	AOAD/M_T	AUST	0.0035
TUVA	ASHTECH UZ-12	ASH701945C_M	SCIS	0.0000
VANU	ASHTECH UZ-12	ASH701945C_M	SCIS	0.0000

Data Processing Scheme

The processing engine of the Bernese GPS software (Version 5.0) was used to carry out the data processing. The data of six IGS reference stations surrounding the area at the time of the campaign, i.e. ASPA, CHAT, DARW, HOB2, TIDB and TOW2, were included in the analysis to serve as ties with the global reference frame ITRF2005 as illustrated in Figure 2 (Altamimi et al., 2007). These IGS stations were selected because they are IGS Reference Frame (RF) stations used for the IGS realization (IGS05) of the ITRF2005. They have reliable published ITRF2005 positions and velocities at epoch 2000.0 with a long observation history as permanent stations (Altamimi et al., 2007) such that their coordinates can be accurately propagated to the epoch of the measurements.

In order to aid ambiguity resolution and to reduce baseline lengths between the above IGS stations and the Fiji campaign stations, data from 11 CGPS stations of the South Pacific Sea Level and Climate Monitoring Project (SPSLCMP), LAUT, CKIS, KIRI, NAUR, PNGM, POHN, SAMO, TONG, TUVA, VANU and MAJU, were included in the regional daily solutions together with data from a selection of other IGS sites within the area, AUCK, FALE, KOUC and SUNM, where the data were available during the period of the campaign. Fig. 2 shows the extended regional network of IGS and SPSLCMP sites used in the GPS data processing. Table 2 lists the receivers, antennas and antenna heights for the above IGS stations and SPSLCMP stations included in the data analysis.

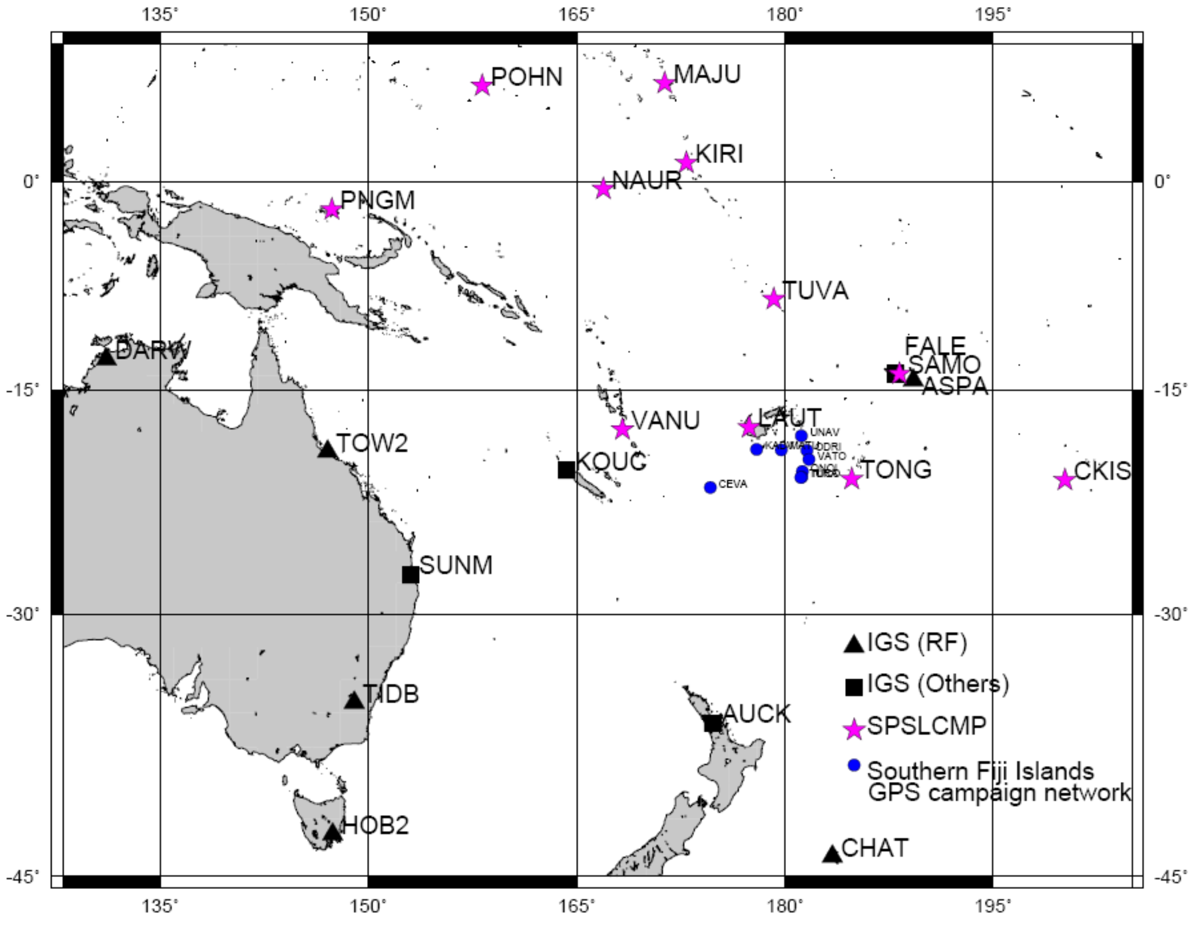

Figure 2: *The SPSLCMP/IGS stations included in the GPS data processing.*

The models applied and processing strategy adopted adhered closely to the procedures typically used by IGS Analysis Centres and Regional Network Associate Analysis Centres in the routine generation of final IGS products with the following particular points highlighted in this study (e.g., Steigenberger et al., 2006):

(1) IGS final precise GPS satellite ephemerides and Earth orientation parameters in ITRF2005 were used for the daily solutions.

(2) To achieve the highest accuracy positions, the IGS absolute antenna phase centre variation (PCV) models were used to correct for both receiver and satellite antenna phase centre offsets (Ge et al., 2005).
(3) During the processing, baseline selection was driven by the following considerations: let the baseline length be as short as possible, and if possible, the same receiver and antenna types should be connected.
(4) Site displacements due to ocean tidal loading for all stations were corrected by using the GOT00.2 model (e.g., Scherneck, 1991).

The final solution (see Tables 6 and 7) was generated using a minimum constraints approach using the above six IGS reference stations (i.e. ASPA, CHAT, DARW, HOB2, TIDB and TOW2) as constraints (Hugentobler et al., 2006; Altamimi et al., 2007). Table 3 lists the ITRF2005 (IGS05 realization) coordinates and velocities of the six IGS reference stations at epoch 2000.0. As part of this process the daily solutions were compared with the combined solution and the resulting differences were analysed for the presence of outliers and computation of the daily repeatability.

Table 3. The IGS05 realization of ITRF2005 coordinates and velocities for the six IGS Reference Frame stations at epoch 2000.0.

SITE	X	Y	Z
		Coordinates (m)	
ASPA	-6100259.9844	-996503.7575	-1567978.0332
CHAT	-4590670.9849	-275482.8716	-4404596.7082
DARW	-4091358.9070	4684606.7121	-1408580.2927
HOB2	-3950071.4760	2522415.2101	-4311638.2398
TIDB	-4460996.2402	2682557.0825	-3674443.5584
TOW2	-5054582.7913	3275504.4130	-2091539.5466
		Velocity (m/yr)	
ASPA	-0.0184	0.0617	0.0329
CHAT	-0.0257	0.0387	0.0244
DARW	-0.0350	-0.0146	0.0569
HOB2	-0.0403	0.0087	0.0408
TIDB	-0.0371	0.0006	0.0455
TOW2	-0.0321	-0.0136	0.0522

Results

THE REPEATABILITY RMS (ROOT MEAN SQUARE) OF THE STATION COORDINATES

The repeatability RMS (root mean square) of the station coordinates, which is an estimate of the day-to-day scatter of coordinate components about a weighted epoch mean, can be used to assess the quality of the final combined epoch solution and as a measure of internal precision. Table 4 shows the repeatability RMS of the station coordinates for each station included in the data analysis. The agreement between the final combined campaign and daily solutions is at the few millimetres to sub-millimetre level for the horizontal components and at the few millimetre level for the vertical component. The average of the repeatability RMS of the station coordinates are 3.0 mm, 1.9 mm and 6.3 mm for the easting, northing and height components, respectively.

For the purpose of comparison, Table 5 lists the difference in coordinate values between the coordinates estimated in this data analysis and the coordinates published by IERS in the ITRF2005 solution for the IGS site AUCK.

Table 4. The repeatability RMS (root mean square) of the station coordinates for each station for the data analysis.

SITE	EAST (mm)	NORTH (mm)	UP (mm)
CEVA	1.67	1.55	2.40
KADV	2.54	0.92	4.14
MATU	1.72	1.12	4.34
ODRI	1.54	1.66	7.49
ONOI	2.01	0.60	3.17
TUCO	2.22	0.87	5.02
TURA	4.73	2.91	2.64
UNAV	2.62	1.20	3.97
VATO	2.53	1.55	4.86
ASPA	3.72	1.77	9.07
AUCK	1.99	1.85	5.66
CHAT	2.04	2.55	4.63
CKIS	3.51	2.12	4.87
DARW	3.37	2.00	5.47
FALE	0.68	1.41	2.13
HOB2	2.39	3.12	5.59
KIRI	4.35	1.26	3.71
KOUC	1.40	1.18	5.53
LAUT	1.85	0.85	2.50
MAJU	3.80	1.30	8.79
NAUR	4.68	1.38	5.97
PNGM	4.50	4.60	5.05
POHN	3.87	2.35	7.00
SAMO	3.08	2.09	2.61
SUNM	1.40	1.97	5.31
TIDB	4.06	2.27	4.61
TONG	2.34	0.64	3.93
TOW2	2.37	1.47	3.46
TUVA	2.89	3.01	2.23
VANU	1.43	0.78	1.95

Table 5. The difference in coordinate values between the coordinates estimated in this data analysis and those published by IERS in the ITRF2005 solution for the IGS site AUCK.

SITE	EAST (mm)	NORTH (mm)	UP (mm)
AUCK	0.6	1.0	3.3

FINAL COMPUTED STATION COORDINATES

The final computed geodetic and Cartesian coordinates (ITRF2005, GRS80 ellipsoid) are listed in Tables 6 and 7, respectively.

Table 6. Final computed geodetic coordinates in ITRF2005 at the mean epoch of the measurements, i.e. @2007.603 (8 August 2007).

SITE	LONGITUDE (DMS)	LATITUDE (DMS)	ELLIPSOIDAL HEIGHT (m)
CEVA	E 174 37 57.47920	S 21 44 10.55364	63.5479
KADV	E 177 59 17.45239	S 19 07 5.31825	860.5357
MATU	E 179 44 59.71645	S 19 10 27.91403	387.6648
ODRI	W 178 24 21.20689	S 19 12 1.06425	130.9099
ONOI	W 178 44 21.36593	S 20 38 34.47590	155.0690
TUCO	W 178 45 12.47489	S 21 00 40.25961	57.0808
TURA	W 178 50 51.74177	S 21 01 54.49938	56.2543
UNAV	W 178 46 47.59242	S 18 11 14.35045	112.6497
VATO	W 178 15 06.88044	S 19 49 43.54319	91.0613
ASPA	W 170 43 20.76851	S 14 19 33.94230	53.6446
AUCK	E 174 50 03.78913	S 36 36 10.23030	132.7114
CHAT	W 176 33 57.03688	S 43 57 20.82399	57.9969
CKIS	W 159 48 02.20254	S 21 12 03.69498	18.4370
DARW	E 131 07 57.86453	S 12 50 37.33286	125.1232
FALE	W 171 59 58.30283	S 13 49 55.96649	47.5893
HOB2	E 147 26 19.44545	S 42 48 16.96117	41.0599
KIRI	E 172 55 22.42026	N 01 21 16.49704	36.1754
KOUC	E 164 17 14.41235	S 20 33 31.29180	84.1842
LAUT	E 177 26 47.69055	S 17 36 31.72706	89.6832
MAJU	E 171 21 52.27644	N 07 07 08.93356	33.7000
NAUR	E 166 55 31.97673	S 00 33 06.22863	46.2622
PNGM	E 147 21 57.63495	S 02 02 35.62788	116.3521
POHN	E 158 12 36.40873	N 06 57 35.80075	90.6783
SAMO	W 171 44 18.32206	S 13 50 57.15651	76.8809
SUNM	E 153 02 07.08084	S 27 29 5.61155	92.0461
TIDB	E 148 58 47.99535	S 35 23 57.13214	665.3537
TONG	W 175 10 45.18906	S 21 08 40.96688	56.3270
TOW2	E 147 03 20.47968	S 19 16 9.40361	88.1310
TUVA	E 179 11 47.61176	S 08 31 31.04516	38.4268
VANU	E 168 18 54.53439	S 17 44 38.30912	97.5890

Table 7. Final computed Cartesian coordinates in ITRF2005 at the mean epoch of the measurements, i.e. @2007.603 (8 August 2007).

SITE	X (m)	Y (m)	Z (m)
CEVA	-5901432.295	554458.552	-2347334.805
KADV	-6025613.941	211663.544	-2075992.097
MATU	-6026782.908	26305.253	-2081722.468
ODRI	-6023324.388	-167626.921	-2084343.306
ONOI	-5969817.808	-131380.591	-2234496.561
TUCO	-5955264.956	-129583.998	-2272571.377
TURA	-5954650.392	-119772.048	-2274702.372
UNAV	-6060202.213	-129071.474	-1978127.194
VATO	-5999585.503	-183103.599	-2149904.639
ASPA	-6100260.118	-996503.285	-1567977.780
AUCK	-5105681.259	461564.027	-3782181.415
CHAT	-4590671.191	-275482.572	-4404596.528
CKIS	-5583182.276	-2054143.411	-2292166.637
DARW	-4091359.179	4684606.601	-1408579.860
FALE	-6134111.986	-862144.688	-1514974.362
HOB2	-3950071.777	2522415.270	-4311637.925
KIRI	-6327822.445	785604.349	149769.163
KOUC	-5751222.899	1617967.472	-2225743.765
LAUT	-6075194.567	270923.916	-1917189.448
MAJU	-6257572.299	950332.653	785215.223
NAUR	-6212555.101	1442786.867	-61006.686
PNGM	-5367943.053	3437431.437	-225885.900
POHN	-5879158.613	2350291.989	767748.287
SAMO	-6129702.318	-890029.183	-1516807.322
SUNM	-5046794.079	2567554.654	-2926027.699
TIDB	-4460996.523	2682557.090	-3674443.218
TONG	-5930303.688	-500147.631	-2286366.206
TOW2	-5054583.030	3275504.304	-2091539.147
TUVA	-6307543.782	88454.554	-939278.000
VANU	-5950766.632	1230703.818	-1931445.032

Transformation between ITRF2005@2007.603 and Fiji WGS72 Geodetic Datum

FIJI WGS72 GEODETIC DATUM VALUES SUPPLIED BY SOPAC

Table 8 lists the Fiji WGS72 geodetic datum coordinates supplied by SOPAC for six of the nine geodetic sites in the southern Fiji Islands archipelago. WGS72 coordinates are unavailable for the other 3 sites. Table 9 lists the Fiji WGS72 geodetic datum coordinates converted to Cartesian values.

Geoid-ellipsoid separations (N values) were derived from EGM96 N values for these sites by the method described below. This was required to enable derivation of ellipsoidal height values for sites ODRI and UNAV. The agreement between the WGS72 N values derived from the EGM96 N values with those WGS72 N values derived from the SOPAC supplied MSL height and ellipsoidal height values is acceptable considering the accuracy of the EGM96 N values and the accuracy of precise Transit Doppler positioning systems.

Table 8. Fiji WGS72 geodetic datum coordinates.

SITE	LONGITUDE [c] (DMS)	LATITUDE [c] (DMS)	MSL [c] HEIGHT (m)	N (m)	ELLIPSOIDAL HEIGHT (m)
KADV [e]	E 177 59 16.925	S 19 07 05.393	805.3	57.48 [a] 57.45 [b]	862.75 [c]
MATU [e]	E 179 44 59.199	S 19 10 27.984	334.0	52.43 [a] 55.57 [b]	389.57 [c]
ODRI	W 178 24 21.6827	S 19 12 01.1761	77.03	53.25 [a] -	130.28 [d]
ONOI [e]	W 178 44 21.899	S 20 38 34.631	100.2	54.05 [a] 54.65 [b]	154.85 [c]
UNAV	W 178 46 48.070	S 18 11 14.440	59.77	52.82 [a] -	112.59 [d]
VATO [e]	W 178 15 07.427	S 19 49 43.622	34.1	53.54 [a] 57.47 [b]	91.57 [c]

Note ***a.*** *WGS72 N value derived from EGM96 N value using the method described below.*
Note ***b.*** *WGS72 N value derived by subtracting MSL Height from Ellipsoidal height.*
Note ***c.*** *Values supplied by SOPAC.*
Note ***d.*** *Ellipsoidal Height derived by adding MSL height and N value.*
Note ***e.*** *Royal Australian Survey Corps (RASvy) station with precise ephemeris Transit Doppler WGS72 position.*

Table 9. Fiji WGS72 geodetic datum coordinates (Cartesian values).

SITE	X (m)	Y (m)	Z (m)
KADV	-6025612.829	211678.930	-2075994.466
MATU	-6026782.025	26320.369	-2081724.597
ODRI	-6023321.140	-167612.926	-2084345.816
ONOI	-5969814.367	-131365.080	-2234500.378
UNAV	-6060199.677	-129057.382	-1978129.289
VATO	-5999583.742	-183087.633	-2149906.544

DERIVATION OF WGS72 N VALUES FROM EGM96 N VALUES

EGM96 N values were computed for the six sites having WGS72 coordinates using the online National Geospatial-Intelligence Agency (NGA) EGM96 geoid calculator at http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm96/intpt.html.

The EGM96 N values were converted to N values in the WGS72 system using the formulae listed at Table E.1 of NIMA Technical report TR8350.2. These formulae are:

$$N_{WGS72} = N_{WGS84} - \Delta h$$

where:

$$N_{WGS84} = EGM96\ \ N\ \ value$$

$$\Delta h = 4.5 \sin\phi + 0.1991 \sin^2\phi - 0.6$$

$$\phi = latitude\ \ of\ \ site$$

Table 10 lists both EGM96 and WGS72 N values.

Table 10. EGM96 and WGS72 N values.

SITE	N_{EGM96} (m)	N_{WGS72} (m)
KADV	55.43	57.48
MATU	50.37	52.43
ODRI	51.19	53.25
ONOI	51.89	54.05
UNAV	50.83	52.82
VATO	51.44	53.54

DETERMINATION OF 7-PARAMETER TRANSFORMATION VALUES

A 7-parameter Helmert transformation was computed between the ITRF2005@2007.603 and Fiji WGS72 geodetic datum coordinate sets for the six common sites. The following formula represents the 7-parameter transformation for small rotation angles (R_X, R_Y, R_Z):

$$\begin{bmatrix} X_{ITRF05} \\ Y_{ITRF05} \\ Z_{ITRF05} \end{bmatrix} = \begin{bmatrix} T_X \\ T_Y \\ T_Z \end{bmatrix} + (1+S) \times \begin{bmatrix} 1 & R_Z & -R_Y \\ -R_Z & 1 & R_X \\ R_Y & -R_X & 1 \end{bmatrix} \begin{bmatrix} X_{WGS72} \\ Y_{WGS72} \\ Z_{WGS72} \end{bmatrix}$$

Where:

(X_{ITRF05}, $Y_{ITRF05,}$ Z_{ITRF05})	are the transformed Cartesian coordinates (m) consistent with the ITRF05@2007.603 coordinates listed in this report.
(X_{WGS72}, $Y_{WGS72,}$ Z_{WGS72})	are the Cartesian Fiji WGS72 geodetic datum coordinates (m).
(T_X, T_Y, T_Z)	are the coordinate origin translation parameters (m).
(RX, RY, RZ)	are the coordinate axis rotations (radians).
S	is the scale change between both coordinate systems.

<u>Important Note:</u>

There are two different ways of applying the sign conventions for the rotations. In both cases the sign convention is the same (a positive rotation is an anti-clockwise rotation, when viewed along the positive axis towards the origin) but:

a) the International Earth Rotation Service (IERS) assumes the rotations to be of the position around the coordinate axes, while
b) the method historically used in Australia assumes the rotations to be of the coordinate axes.

The only difference in the transformation formula is a change in the signs of the rotation angles in the rotation matrix. If the sign of the rotation parameters and the formulae used are consistent the correct results will be obtained. In this document the method historically used in Australia (b) is adopted.

Table 11 lists the 7-parameter transformation values and Table 12 lists the coordinate residuals resulting from the least squares transformation computation process. These residuals are consistent with the accuracy of precise Transit Doppler positioning systems. Figure 3 shows the location of the six sites used to derive the 7-parameter transformation and the suggested boundary of the region where these parameters may be considered to be valid.

Table 11. 7-parameter transformation values- Fiji(WGS72) geodetic datum to ITRF05@2007.603.

T_X (m)	T_Y (m)	T_Z (m)	R_X (“)	R_Y (“)	R_Z (“)	S (ppm)
-16.594	-43.725	-2.677	+0.3014	+0.0029	+1.0842	-2.447

Table 12. 7-paramater transformation coordinate residuals.

SITE	East (m)	North (m)	Up (m)
KADV	+0.20	-0.48	-0.27
MATU	+0.04	+0.42	+0.69
ODRI	+0.72	-0.10	-0.52
ONOI	-0.21	-1.14	-0.43
UNAV	+0.36	+0.13	-0.16
VATO	-1.12	+1.17	+0.69

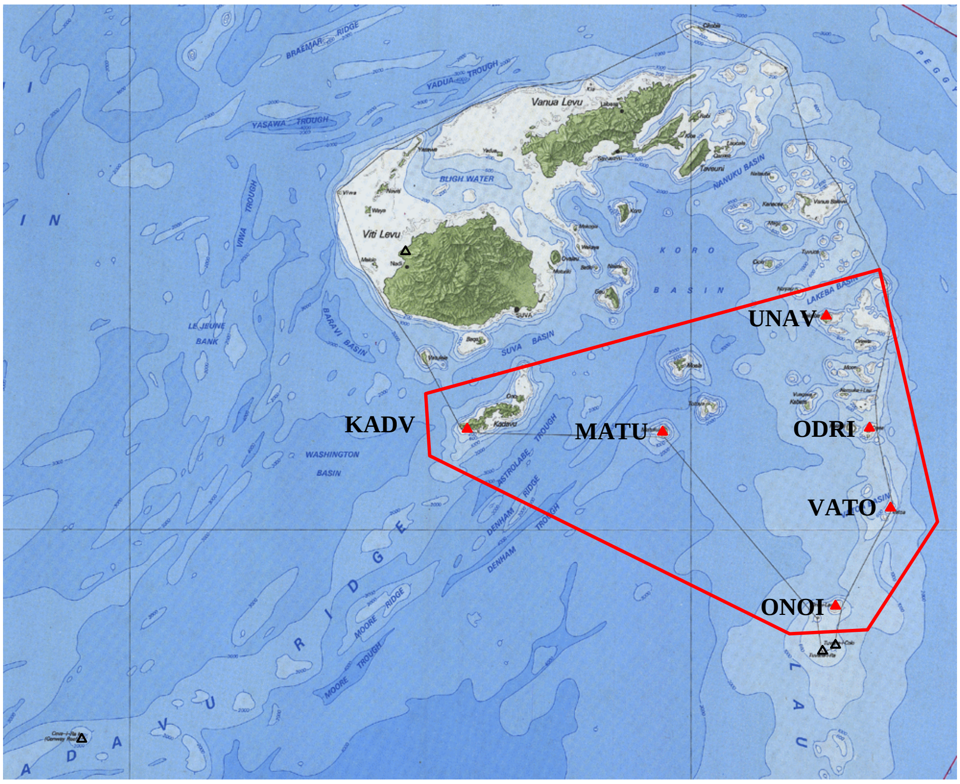

Figure 3: *Distribution of sites used to compute 7-parameter transformation.*

LIMITATIONS OF THE DETERMINED 7-PARAMETER TRANSFORMATION

The 7-parameter transformation has been determined with the following premises about the Fiji WGS72 geodetic datum coordinates:

- Three stations (CEVA, TUCO, and TURA) are new marks without WGS72 coordinates and were not used in the determination of the transformation parameters.
- Four stations have precise ephemeris Transit Doppler WGS72 coordinates (KADV, MATU, ONOI and VATO) observed in the early 1980s.
- Two stations (ODRI and UNAV) have WGS72 coordinates determined by survey methods other than Transit Doppler measurement.
- Neither the WGS72 coordinates nor the ITRF2005 coordinates were propagated to a common epoch of date using crustal motion coordinate velocities. There are no measurements available to determine reliable crustal motion vectors for these stations.
- It is unknown if the crustal motion in the southern Fiji archipelago is uniform or non-uniform.. Any non-uniform crustal motion will contribute additional error to the transformation parameters due to the approximate 25 year time difference between the Transit Doppler surveys and the 2007 GPS survey campaign.
- Any error sources in the propagation of the WGS72 coordinates within each island group will contribute additional error to the transformation parameters.

The above factors need to be considered when assessing the quality or accuracy of any ITRF2005 coordinate determined by transformation from a Fiji WGS72 geodetic datum coordinate. The suggested boundary of the region where these transformation parameters may be considered valid is shown by the polygon in Figure 3.

References

Altamimi, Z., X. Collilieux, J. Legrand, B. Garayt, and C. Boucher, 2007. ITRF2005: A new release of the International Terrestrial Reference Frame based on time series of station positions and Earth Orientation Parameters, *J. Geophys. Res.*, 112, B09401, doi:10.1029/2007JB004949.

Ge, M., Gendt, G., Dick, G., Zhang, F.P., Reigber,C., 2005. Impact of GPS satellite antenna offsets on scale changes in global network solutions. *Geophys. Res. Lett.* 32, L06310. doi:10.1029/2004GL022224.

Hugentobler U., Dach R., P. Fridez and M. Meindl (eds), 2006. *Bernese GPS Software, Version 5.0 DRAFT*, Astronomical Institute, University of Berne.

National Imagery and Mapping Agency, *Department of Defense World Geodetic System 1984*, NIMA TR8350.2, Third Edition, January 2000.

Niell, A.E., 1996. Global mapping functions for the atmosphere delay at radio wavelengths. *J. Geophys. Res.*, 101(B2): 3227-3246.

Scherneck, H.-G., 1991. A parametrized solid Earth tide mode and ocean loading effects for global geodetic base-line measurements. *Geophys. J. Int.*, 106(3):677-694, 1991.

Steigenberger P., M.Rothacher, R.Dietrich, M.Fritsche, A.Rülke and S.Vey, 2006. Reprocessing of a global GPS network. *J. Geophys. Res. 111*, B05402,doi:10.1029/2005JB003747.