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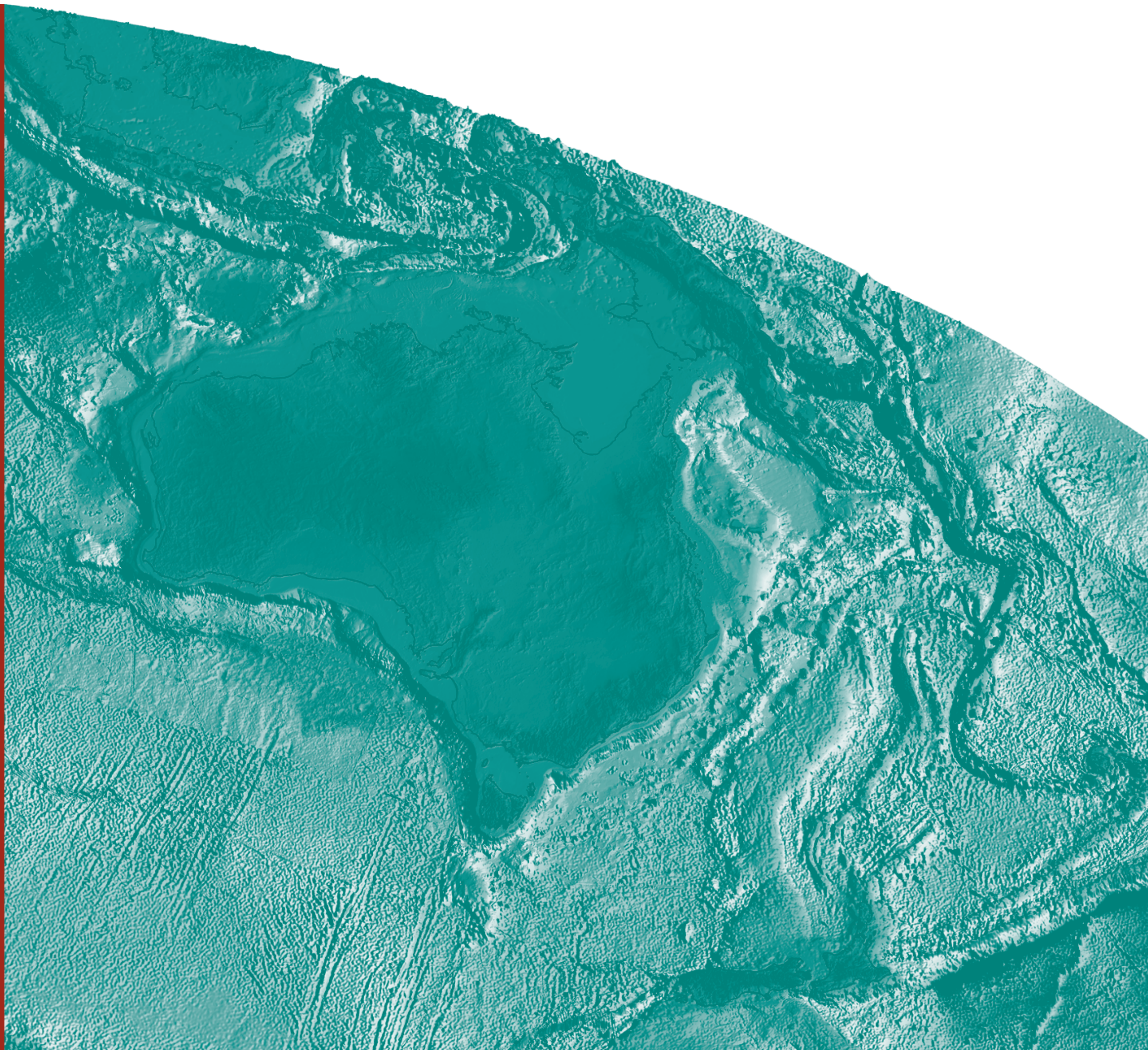

APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

A Report on the Analysis of the Asia Pacific Regional Geodetic Project (APRGP) GPS Campaign 2010

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by

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 and Energy: The Hon. Martin Ferguson, AM MP
Secretary: Drew Clarke

Geoscience Australia
Chief Executive Officer: Dr Chris Pigram

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Executive Summary

A REPORT ON THE ANALYSIS OF THE ASIA PACIFIC REGIONAL GEODETIC PROJECT (APRGP) GPS CAMPAIGN IN 2010

The annual Asia Pacific Regional Geodetic Project (APRGP) GPS campaign is an important activity of the Geodetic Technologies and Applications Working Group (WG) of the Permanent Committee on GIS Infrastructure for Asia and the Pacific Region (PCGIAP). This document overviews the data analysis of the APRGP GPS campaign undertaken in 2010. The GPS data was processed using version 5.0 of the Bernese GPS Software in a regional network together with selected IGS (International GNSS Service) 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.

Introduction

The Permanent Committee on GIS Infrastructure for Asia and the Pacific Region (PCGIAP) executive board meeting was held in Tehran, Iran on 17 May 2010, and a decision was made to continue the annual GPS campaign activity as some member countries are at this time unable to participate in the Asia Pacific Reference Frame (APREF) project but have a requirement for geodetic positioning relative to the regional/global network. The annual APRGP GPS campaign is an important activity of the Geodetic Technologies and Applications Working Group (WG) of the PCGIAP. The role of the WG is to coordinate regional cooperation in geodesy amongst national agencies, and to build and improve the regional geodetic infrastructure. The APRGP is where PCGIAP member agencies contribute campaign or continuous GPS data to the WG. GPS data from the APRGP are available for all participant member countries for local and global scientific research and local applications. The composite GPS data-set is subsequently analysed by the WG so as to provide estimates of station coordinates in the International Terrestrial Reference Frame (ITRF). The results of the APRGP are also supplied by the WG to the official ITRF product centre to densify the ITRF in the Asia-Pacific region. This document overviews the data analysis of APRGP GPS campaign undertaken in 2010.

The document is organized as follows. The data set of the campaign is described first. The data processing scheme is detailed after, followed by the results of processing including the repeatability RMS (root mean square) of the station coordinates, and the final computed station coordinates.

GPS Data Set

The 2010 GNSS campaign was undertaken from 12 to 18 September 2010 inclusive (days of year 255 to 261). The data were contributed from seven countries and regions, i.e., Cambodia, Hong Kong, Japan, Malaysia, Philippines, Singapore and Vietnam. Note that Hong Kong and Philippines also contribute CGPS data to the APREF project. Figure 1 shows the distribution of the APRGP 2010 campaign stations along with the APREF stations (as of 02 May 2011).

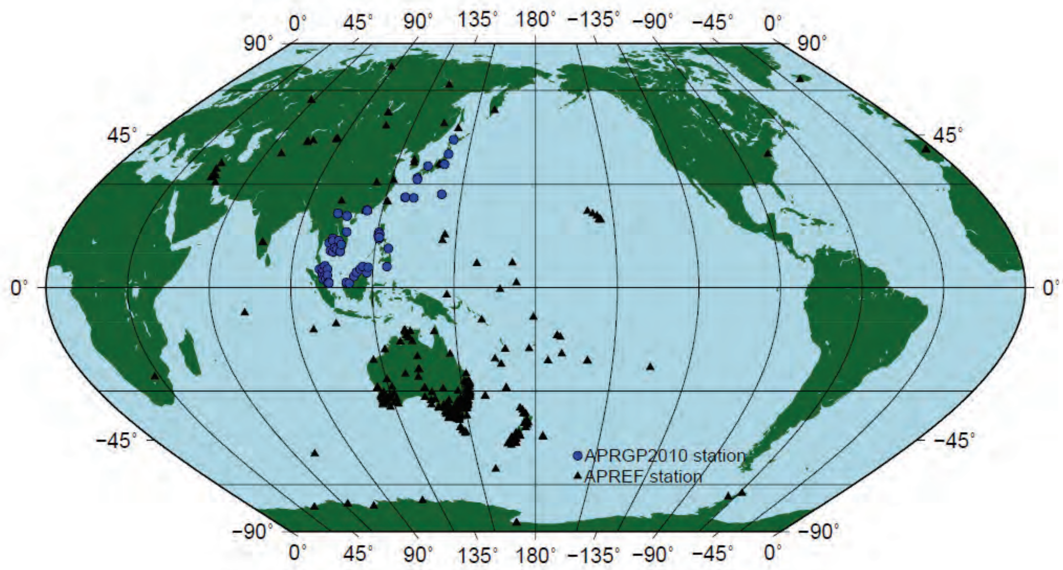

Figure 1: *APRGP and APREF stations in the APRGP 2010 GPS campaign analysis.*

Data Processing Scheme

Analysis of the GPS observations was undertaken with the processing engine of Bernese GPS software V5.0 (Dach et al., 2007). The Bernese GPS software conforms to the IERS2003 conventions (McCarthy and Petit, 2004). In order to tie the APRGP network to the ITRF2005 reference frame (Altamimi et al., 2007), we processed the available data from IGS sites located around the Asia Pacific region in addition to campaign sites and APREF stations as shown in Figure 1.

An overview of the processing strategy is as follows:

1) IGS final precise GPS satellite ephemeris and the Earth rotation parameters were used for the daily data processing to generate daily normal equations.
2) Site displacement due to ocean tidal loading for all stations were corrected by using the GOT00.2 model (Scherneck, 1991).
3) Antenna phase centre variations were taken into consideration using consistent, absolute IGS models of both receiver and satellite antenna phase centres (Schmid et al., 2007).
4) Dual frequency carrier phase and code data were used with an elevation cut off angle of 10° and elevation-dependent weighting ($w = \cos^2 z$, where z is the zenith angle). Code measurements were only used for receiver clock synchronisation. Pre-processing used the full sampling rate of 30 seconds, a sampling rate of three minutes was used for other processing.
5) Carrier phase pre-processing was conducted on a baseline by baseline mode using triple differences. The observations with small pieces and the observations suspected to be corrupted by a cycle slip were marked. Subsequent processing did not use the marked observations. Using different linear combination of L1 and L2 cycle slips were fixed if possible. New ambiguity parameters were introduced if cycle slips could not be fixed reliably, or if significant gaps in the observations where present. In addition, a data screening step in a baseline by baseline mode was performed on the basis of weighted post-fit residuals and outliers were marked and removed for the further processing.
6) An a priori dry tropospheric delay computed from a standard atmosphere was mapped with the Dry Niell mapping function (Niell, 1996). For the wet component, continuous piecewise linear troposphere parameters were estimated in 1-hour intervals without any a priori model using the wet Niell mapping function and the ionosphere-free combination observations.
7) After the pre-processing, ionosphere maps were estimated using the geometry-free linear combination. The vertical electron content was modelled with a single-layer model in a solar geomagnetic reference frame. The height of the single layer was 450 km above the Earth's surface. The previously estimated ionosphere maps were introduced as a priori ionosphere information and, in addition, stochastic ionosphere parameters were set up to support the Quasi Ionospheric Free (QIF) ambiguity resolution strategy (Dach et al., 2007).
8) Ambiguity resolution was attempted on all baselines within the network using the QIF strategy with ionospheric and tropospheric delay supporting. The QIF strategy is based on the ionospheric free linear combination, but also incorporates the estimation of an ionospheric parameter for each epoch to account for the residual ionospheric biases, details can be found in Dach et al. (2007).
9) The daily normal equations were generated and combined into a campaign solution. 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 the daily repeatability.

Results

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

The repeatability RMS (root mean square) of the station coordinates, an estimate of the day-to-day scatter of coordinate components about a weighted epoch mean, was used to assess the quality of the final epoch solution and as a measure of internal precision. Table 1 lists the repeatabilities RMS of the station coordinates. The average of the repeatabilities (i.e. RMS) of the station coordinates for the campaign was 1.8, 2.1 and 6.0 mm in north, east and up components, respectively.

Table 1. The repeatability RMS for the campaign stations.

Station	Country/Region	North (mm)	East (mm)	Up (mm)
0029 21702S011	Japan	1.2	2.0	3.2
0100 21742S001	Japan	1.7	2.5	8.9
0745	Japan	1.7	2.2	6.4
0746	Japan	2.2	1.8	5.8
0837 21742S001	Japan	2.0	1.4	3.2
1135	Japan	1.4	1.5	5.8
2003 21732S003	Japan	1.3	1.4	4.8
2004	Japan	1.5	4.4	7.1
2005	Japan	1.6	1.6	4.4
3009	Japan	1.6	2.2	4.1
AMAN	Malaysia	1.9	2.2	3.6
ARAU	Malaysia	2.7	1.8	9.1
BEHR	Malaysia	2.3	3.3	6.1
BIN1	Malaysia	3.5	3.4	11.4
COOK	Japan	1.4	2.3	8.6
DIEB	Vietnam	1.3	2.3	4.6
DOSN	Vietnam	3.9	3.3	6.8
GAMB	Japan	1.2	2.6	7.8
GETI	Malaysia	2.8	2.0	5.8
GMUS	Malaysia	2.5	1.7	8.2
GRIK	Malaysia	2.2	2.7	4.1
HKFN HKM000065	Hong Kong	1.0	2.3	9.4
HKKT	Hong Kong	1.3	1.6	6.8
HKLT	Hong Kong	0.8	1.4	6.4
HKQT	Hong Kong	1.5	2.9	12.2
HKSC HKM000069	Hong Kong	1.3	1.9	9.3
HKSL HKM000068	Hong Kong	1.7	1.4	4.6
HKST	Hong Kong	1.0	1.6	7.7
JHJY	Malaysia	1.4	1.2	11.7
KAND	Cambodia	2.2	2.6	9.1
KUAL	Malaysia	1.9	1.7	8.2
LAB1	Malaysia	2.3	3.0	9.3
MIRI	Malaysia	1.0	4.0	3.1
MOND	Cambodia	4.4	5.6	5.4
MTAW	Malaysia	1.4	1.9	10.1
NT01	Vietnam	1.1	2.1	7.9
NT03	Vietnam	1.6	2.6	5.2
NT04	Vietnam	1.7	4.2	12.0
ODDA	Cambodia	0.9	2.3	3.9
PCAB	Philippines	2.3	3.2	8.2
PDIC	Malaysia	2.3	1.7	7.5
PEKN	Malaysia	2.1	2.8	7.3
PFLO	Philippines	1.1	2.4	11.9
PGEN	Philippines	0.8	2.0	8.2
PLIN	Cambodia	2.2	3.0	7.4
PTAC	Philippines	1.6	1.7	10.0

Table 1. Continued.

Station	Country/Region	North (mm)	East (mm)	Up (mm)
PTAG PHM000142	Philippines	1.1	1.7	10.3
PTGY	Philippines	1.5	1.8	6.1
PURD	Philippines	1.3	2.5	8.6
QT01	Vietnam	2.5	1.7	10.3
SAND	Malaysia	1.4	3.2	7.0
SEG1	Malaysia	2.5	3.2	11.2
SIEM	Cambodia	1.6	2.1	3.0
SIHA	Cambodia	2.6	2.9	8.4
SKEP	Singapore	2.0	2.9	6.1
SLOY	Singapore	2.4	2.3	6.2
SNTU	Singapore	2.5	2.0	10.7
SNYP	Singapore	2.8	2.0	5.8
SSEK	Singapore	1.9	2.5	7.0
SSMK	Singapore	2.2	2.3	7.2
STUE	Cambodia	2.5	2.7	3.7
SVAY	Cambodia	4.7	4.1	6.2
T430 HKM000070	Hong Kong	1.4	1.5	8.1
TLOH	Malaysia	2.5	2.4	9.9
TSKB 21730S005	Japan	1.8	1.8	5.8
UMAS	Malaysia	1.3	2.2	6.0
UMSS	Malaysia	1.6	4.5	4.6
USMP	Malaysia	1.6	2.9	9.5
VT04	Vietnam	2.0	3.4	5.3
VUNT	Vietnam	2.3	2.2	9.6

FINAL COMPUTED STATION COORDINATES

The final computed Cartesian coordinates (ITRF2005, GRS80 ellipsoid) are listed in Table 2 along with their formal error estimates, which can be the first indication of the quality of the measurements and characterizes the internal precision of positioning performance. Note that the listed coordinates are at the mean epoch of the measurements in the ITRF2005 reference frame.

Table 2. The final computed Cartesian coordinates in ITRF2005 at the mean epoch of the measurements, i.e. @2010.7068.

SITE 4-char. ID	X (m)	1σ (m)	Y (m)	1σ (m)	Z (m)	1σ (m)
0029	-3862395.456	0.0004	3105010.702	0.0004	4001962.405	0.0004
0100	-3509124.782	0.0005	4529006.939	0.0005	2793529.237	0.0004
0745	-3512919.887	0.0004	4524558.139	0.0005	2795882.086	0.0003
0746	-3786805.140	0.0004	4311846.058	0.0004	2774485.415	0.0003
0837	-3530185.631	0.0006	4118797.294	0.0006	3344036.860	0.0005
1135	-3591930.904	0.0004	3758797.111	0.0004	3682342.847	0.0004
2003	-4488925.593	0.0005	3483903.247	0.0004	2887743.351	0.0003
2004	-3565271.682	0.0004	4118973.134	0.0005	3306293.173	0.0004
2005	-3642161.321	0.0004	2861487.859	0.0004	4370351.309	0.0005
3009	-3997615.508	0.0004	3276762.751	0.0003	3724230.521	0.0003
AMAN	-2332691.793	0.0003	5934768.365	0.0007	135097.429	0.0002
ARAU	-1131051.805	0.0003	6236311.783	0.0008	711747.990	0.0002
BEHR	-1270756.603	0.0003	6236377.958	0.0007	416063.889	0.0002
BIN1	-2497850.068	0.0004	5857731.728	0.0007	358111.943	0.0002
COOK	-5583616.941	0.0008	-2053000.149	0.0004	-2292142.397	0.0004
DIEB	-1336842.292	0.0002	5787988.456	0.0006	2315702.222	0.0003
DOSN	-1724757.243	0.0004	5714523.883	0.0009	2239792.021	0.0004

Table 2. Continued.

SITE 4-char. ID	X (m)	1σ (m)	Y (m)	1σ (m)	Z (m)	1σ (m)
GAMB	-4147126.706	0.0007	-4152222.193	0.0007	-2490033.162	0.0005
GETI	-1329733.202	0.0002	6199766.549	0.0006	687129.451	0.0002
GMUS	-1317445.107	0.0002	6217407.695	0.0006	537098.018	0.0002
GRIK	-1225760.634	0.0002	6230325.990	0.0005	600544.086	0.0002
HKFN	-2411013.257	0.0003	5380268.152	0.0006	2425128.962	0.0003
HKKT	-2405144.262	0.0003	5385195.130	0.0006	2420032.408	0.0003
HKLT	-2399063.100	0.0003	5389237.724	0.0005	2417326.921	0.0003
HKQT	-2421568.258	0.0004	5384910.455	0.0007	2404264.265	0.0004
HKSC	-2414267.274	0.0004	5386768.859	0.0007	2407459.894	0.0003
HKSL	-2393382.779	0.0004	5393861.056	0.0006	2412592.268	0.0003
HKST	-2417143.242	0.0004	5382345.368	0.0006	2415036.811	0.0003
JHJY	-1520490.113	0.0004	6191944.477	0.001	169912.709	0.0003
KAND	-1612533.371	0.0003	6039786.957	0.0008	1261186.376	0.0002
KUAL	-1443668.357	0.0003	6184650.130	0.0007	587309.870	0.0002
LAB1	-2708735.406	0.0004	5744698.533	0.0007	583318.796	0.0002
MIRI	-2586925.329	0.0003	5809853.386	0.0006	482986.927	0.0002
MOND	-1839913.094	0.0004	5951524.856	0.0009	1367838.852	0.0003
MTAW	-2974552.700	0.0005	5622306.046	0.0007	470932.481	0.0002
NT01	-1726969.473	0.0003	5714864.901	0.0009	2237081.370	0.0004
NT03	-1916791.325	0.0003	5822974.844	0.0008	1754668.659	0.0003
NT04	-1575936.465	0.0004	6075089.184	0.001	1132070.055	0.0003
ODDA	-1445283.113	0.0003	6013556.019	0.0009	1553365.724	0.0003
PCAB	-3161422.944	0.0004	5274253.051	0.0005	1688186.532	0.0002
PDIC	-1304197.815	0.0002	6237114.366	0.0006	279242.738	0.0002
PEKN	-1474284.656	0.0002	6193341.600	0.0006	385958.626	0.0002
PFLO	-3127779.017	0.0004	5310051.197	0.0006	1638298.797	0.0003
PGEN	-3650005.807	0.0004	5187337.153	0.0005	669409.151	0.0002
PLIN	-1357605.470	0.0004	6069462.690	0.001	1409932.010	0.0003
PTAC	-3588936.770	0.0004	5124727.376	0.0005	1236144.130	0.0002
PTAG	-3184317.906	0.0003	5291063.951	0.0004	1590417.759	0.0002
PTGY	-3181285.123	0.0003	5307488.221	0.0005	1543919.102	0.0002
PURD	-3119484.172	0.0002	5279887.068	0.0004	1747196.488	0.0002
QT01	-1339440.796	0.0003	5788398.020	0.0013	2313170.257	0.0007
SAND	-2990750.696	0.0004	5596337.954	0.0007	644936.512	0.0002
SEG1	-1404378.139	0.0002	6215518.727	0.0006	274837.365	0.0002
SIEM	-1481813.705	0.0002	6025851.565	0.0006	1469486.507	0.0003
SIHA	-1466153.695	0.0004	6095949.198	0.001	1166708.017	0.0003
SKEP	-1521817.466	0.0003	6192367.137	0.0007	140106.719	0.0002
SLOY	-1539523.141	0.0003	6187726.069	0.0007	151765.336	0.0002
SNTU	-1508021.391	0.0003	6195577.091	0.0006	148800.743	0.0002
SNYP	-1526242.944	0.0003	6191001.988	0.0007	152484.113	0.0002
SSEK	-1522480.065	0.0003	6191654.886	0.0007	162569.366	0.0002
SSMK	-1518411.129	0.0002	6193330.554	0.0005	133831.331	0.0002
STUE	-1706562.529	0.0003	5962886.420	0.0008	1482541.069	0.0003
SVAY	-1704880.204	0.0005	6023200.866	0.0011	1218618.994	0.0003
T430	-2411015.591	0.0004	5380265.595	0.0007	2425132.561	0.0003
TLOH	-1369260.456	0.0003	6217732.158	0.0007	381198.077	0.0002
TSKB	-3957199.262	0.0005	3310199.740	0.0004	3737711.623	0.0004
UMAS	-2225109.118	0.0003	5975252.648	0.0006	162341.138	0.0002
UMSS	-2791752.152	0.0004	5695647.587	0.0006	666580.636	0.0002
USMP	-1135919.522	0.0003	6248058.509	0.0008	591589.467	0.0002
VT04	-1844373.493	0.0004	5997105.507	0.0011	1142317.019	0.0004
VUNT	-1849616.939	0.0003	5995299.890	0.0007	1143372.707	0.0002

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