

Solutions of the VLBI experiments of Asian-Pacific Space Geodynamics program

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Abstract. During the campaigns of the Asian-Pacific Space Geodynamics (APSG) program in October of 1997 and in November of 1998, four VLBI experiments were successfully organized and coordinated by the Astrometry and Geodesy VLBI Group of Shanghai Astronomical Observatory, Chinese Academy of Sciences, cooperated with geodetic VLBI group, GSFC, NASA, USA. Six VLBI stations participated in the first campaign, including Seshan and Urumqi station of China, Gilcreek station in Alaska and Kokee station in Hawaii of USA, Kashima station of Japan and Hobart station at Tasmania of Australia. In the second campaign, Tsukuba station of Japan participated instead of Kashima station. Baseline lengths are from 1,800 km to 11,000 km. Single solutions show that there are more validate observation points acquired from the second campaign than from the first one, and the corresponding root-mean-squares of the post-fit residuals of delay are about 40 ps and 50 ps. The mean relative uncertainty of the baseline length measurement is about 1.0×10^{-9} . All the four experiments are in well consistent with the planing requirement of observation precision. The evolution of the baselines and the three dimensional velocities of the above mentioned VLBI stations are solved out from global analysis of the four APSG sessions and all the other VLBI observations from the global observation network. These results are appreciable to the studies of the modern crustal movement in the Asian-Pacific region. Especially, an 8 mm/yr eastward motion and a 10 mm/yr north by northeast motion are detected respectively for Seshan and Urumqi station relative to the stable part of the Eurasian plate. The Motions directly illustrate the effect of the northward movement of Indian plate on the modern crustal motions of the northwestern and the eastern part of China, and which is of important significance to the study of the modern crustal motion of China.

1. Introduction

The Asian-Pacific Space Geodynamics (APSG) program is sponsored and organized by Shuhua Ye, Academician of the Chinese Academy of Sciences (CAS), and is an international cooperation program being carried over to the next century. Scientists from related institutions and agencies of Australia, China, Indonesia, Japan, Malaysia, Pakistan, Philippine, Russia, USA and so on participate in this program. The secretariat of the APSG program is at Shanghai Astronomical Observatory (SHAO), CAS. The primary objectives of study for the APSG program are to measure and monitor the modern crustal movement and deformation in the Asian-Pacific region using high precision space geodetic techniques such as Very Long Baseline Interferometry (VLBI), Global Positioning System (GPS) and Satellite Laser Ranging (SLR), and so to investigate various crustal motion rooted natural hazards, such as earthquakes, volcanic eruptions, etc.. The program is expected to contribute to the means for mitigating and preventing natural disasters as well. In October of 1997 and in November of 1998, the astrometry and geodesy group of SHAO, cooperating with GSFC, NASA, USA, coordinated the VLBI experiments of the first and

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the second APSG campaign. For each campaign there are two 24-hour VLBI experiments. The measurement results are presented in this report.

2. The VLBI experiments of the APSG program

The four APSG VLBI experiments were carried out respectively on Oct. 6 and 20 of 1997 and on November 5 and 11 of 1998 (Hereafter referred as APSG1 through APSG4). In the first campaign six VLBI stations participated and in the second campaign Tsukuba station participated instead of Kashima station. In these observations the S/X dual frequencies were adopted with standard frequency sequence. There are eight channels with maximum wide of 360 MHz at X band (wavelength at 3.6 cm) and six channels with maximum wide of 85 MHz at S band (wavelength at 13 cm). Other information on the participated stations and the implementation of the experiments are shown in Table 1 and Table 2.

Table 1. VLBI stations in the APSG campaigns

Station	Code	Location	Institute	Plate	Antenna Diameter
Seshan	SH	Shanghai, China	SHAO, CAS	Eurasian	25m
Urumqi	UR	Urumqi, China	Urumqi Astronomical Station, CAS	Eurasian	25m
Gilcreek	GC	Alaska, USA	NASA, USA	North American	26m
Kashima	KA	Kashima, Japan	Geographical Survey Institute, Japan	North American	26m
Kokee	KK	Hawaii, USA	USNO, USA	Pacific	20m
Hobart	HO	Hobart, Australia	Tasmania University	Australian	26m
Tsukuba	TS	Tsukuba, Japan	Geographical Survey Institute, Japan	North American	32m

Table 2. Observation plans for the APSG VLBI experiments

Session	Start	Stop	Planing points	Correlation
APSG1	UT16:00, Oct. 6,1997	UT16:00, Oct. 7, 1997	2026	Washington correlator, USNO, USA
APSG2	UT16:00, Oct.20,1997	UT16:00, Oct.21,1997	2034	
APSG3	UT18:00, Nov. 5,1997	UT18:00, Nov. 6,1997	1890	
APSG4	UT16:00, Oct.12,1997	UT16:00, Oct.13,1997	2034	

3. Data reduction and experiments assessments

The data were correlated at the Washington Correlator, USNO, USA. The MKIII database

was produced at GSFC, NASA, USA. Single solutions of the four APSG sessions and global analysis of all the available VLBI sessions till the end of 1998 were performed by the astrometry and geodesy VLBI group of SHAO. Since the headstack of the recorder at Kashima station was worn out during APSG1, all the data was lost. After the headstack was replaced, the recorded data at Kashima was very well during APSG2. All the data recorded at other stations are normal.

Data reduction was performed at HP C180 workstation in SHAO with software system CALC8.2/SOLVE. IERS 1996 conventions^[1] are adopted. The celestial reference frame is defined by ICRF95^[2]. The New Mapping Function (NMF) of Niell^[3] is used for the correction of atmospheric delay with cut-off angle at 7 degree. Clock behavior is modeled as piecewise linear function.

Table 3 lists out the results from single solution of the four VLBI experiments. From which it is clear that there are more validate observation points acquired from the last two experiments than from the first two, and the corresponding root-mean-squares of the post-fit residuals of delay are about 40 ps and 50 ps. All the four experiments are in well consistent with the planing requirement of observation precision.

Table 3. Results from single solution

Session	Points			Post-fit residuals (ps)
	Observed	Used	Percentage	
APSG1	1074	858	80	50
APSG2	1704	1533	90	51
APSG3	1636	1335	82	41
APSG4	1864	1700	91	44

Baseline solutions of these experiments are listed in Table 4. It is shown that all the relative uncertainties of the baseline length measurements are as accurate as 1.0×10^{-9} , and that there is good consistence in these experiments. From the differences between the baseline length measurements it is easy to deduce that the mean of the relative uncertainty for the first two sessions is about 1.8×10^{-9} and for the last two sessions is about 0.5×10^{-9} , which illustrates the reliability of the measurements and the solutions. This accuracy is equivalent to 1mm uncertainty on 1000km baseline, and is a representative of the up-to-date advanced international level of precision for VLBI measurement.

4. Solutions to the modern crustal motion of stations

Precise station velocity can only be determined from much more than one session and with sufficient time span. There is already several years accumulation of observations for the above mentioned VLBI stations. The first astrometric and geodetic session of Seshan station was carried out ten years ago, in 1988. While for Urumqi VLBI station it is relatively

late, the first session was in 1994. Still, to the end of 1998 there are four years observations and from which the station velocities can be estimated. In order to study the modern crustal movement in the Asian-Pacific region along with its worldwide background, a global solution is conducted using about 20 years astrometric and geodetic VLBI sessions.

From August 1979 to the end of 1998, there are about 2,800 sessions of astrometric and geodetic VLBI observations, containing nearly 2,200,000 group delay data points. In the global solution the software system, conventions and models adopted are the same as in the above mentioned single solution. The celestial and terrestrial reference frames were tied respectively to ICRF95 and ITRF96[4] by adopting a set of coordinates and/or velocities of sources and stations with constraints such as no net rotation and no net translation.

Results of the baseline variations and station velocities from the global solution are listed in Table 5 and Table 6. Because the number of sessions for Urumqi station is very small, the lengths and variations of baselines related with this station as well as its velocities are not accurately determined. For Gilcreek station, there are 1274 sessions and so this station is of the most accurately determined velocities in this region. While for Trukuba station, the observations are still insufficient for the determination of station velocities and baseline variations.

Fig. 1 through 5 show the measurements of some representative baselines in the Asian-Pacific region. As shown in Fig. 1, though the time span of observations is nearly five years, there are only 13 sessions for the baseline from Seshan to Urumqi. So the four VLBI sessions of the APSG program are very essential to the determination of the baseline variations. Similar situation is also indicated for baselines from Urumqi to Gilcreek, to Kokee (Fig. 2), and to Hobart (Fig. 3). For the baseline from Hobart to Seshan as shown in Fig. 4, there are about nine years observations with 22 sessions. The repeatability of measurement is 1.9×10^{-9} . This baseline is among the best observed ones in this region. Fig. 5 shows the baseline from Gilcreek to Kokee, which is most densely observed. There are about five years observations and 325 sessions, with repeatability of measurement as 1.3×10^{-9} . All the figures from Fig. 1 through 5 show the well consistency of the four VLBI sessions of the APSG program with other sessions. Fig. 6 shows the geological distribution of the stations, VLBI measurements and plate motion model predictions of the modern crustal movements as well as the differences between the measurements and predictions.

From the above VLBI measurements, the followings are illustrated:

1. The mean accuracy of the baseline length measurements for the VLBI stations in the Asian-Pacific region is about 1.0×10^{-9} , which is consistent with the repeatability of baseline length measurement for other VLBI stations in the world.
2. Regarding the VLBI measurements of the station velocities, they are in good consistence with the predictions of NUVEL1A-NNR[5] for stations such as Gilcreek at Alaska of USA and Hobart at Tasmania of Australia. However, they are not well consistent for stations such as Seshan and Urumqi of China, Kashima of Japan and Kokee at Hawaii of USA. So the plate motion model well describes large-scale behaviors of global tectonic plates, rather than contemporary deformations taking place within plates or along boundary regions.
3. The detected eastward motion of Seshan station and the north by northeast motion of Urumqi station are of important significance to the study of the modern crustal movement of China, which indicates the effect of the northward movement of the Indo

plate on the raising Tibetan Plateau and on the motion of the Tian Shan mountain area in the northwest part of China as well as on that of the eastern part of China.

4. The westward motion of the Kashima station of Japan is related with the westward motion of the Pacific plate. As the observations being further accumulated, the determination of the Tsukuba station velocity will become into reality. It is eagerly expected to watch the tectonic behavior of this station.

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Table 4. Baseline length solutions for the four VLBI experiments

Baseline	APSG1	APSG2	Baseline	APSG3	APSG4
	Length and uncertainty (mm)			Length and uncertainty (mm)	
SH-GC	663555820.67 ± 6.14	663555825.15 ± 6.43	GC-HO	/	10953029466.30 ± 10.28
SH-KA	/	1875919827.11 ± 2.75	GC-KK	4728081859.07 ± 2.56	4728081860.17 ± 2.71
SH-KK	7310289506.80 ± 6.33	7310289483.86 ± 6.89	GC-SH	663555798.57 ± 4.95	663555800.92 ± 4.54
SH-HO	7965496135.78 ± 11.04	7965496114.65 ± 11.31	GC-TS	5438877191.87 ± 3.93	5438877188.17 ± 3.95
SH-UR	3249214225.41 ± 5.51	3249214226.53 ± 3.76	GC-UR	6727958572.50 ± 5.81	6727958575.29 ± 4.94
UR-GC	6727958595.27 ± 8.06	6727958592.63 ± 5.59	HO-KK	/	8268607612.94 ± 8.01
UR-KA	/	4484542489.25 ± 3.40	HO-SH	/	7965496049.56 ± 7.90
UR-KK	9052299896.07 ± 10.01	9052299868.98 ± 7.34	HO-TS	/	8087529395.11 ± 8.35
UR-HO	9860482997.84 ± 15.65	9860482981.02 ± 13.28	HO-UR	/	9860482936.81 ± 9.89
GC-KA	/	5427104390.01 ± 4.48	KK-SH	7310289400.13 ± 5.36	7310289400.07 ± 4.66
GC-KK	4728081909.85 ± 3.57	4728081919.19 ± 4.26	KK-TS	5754940527.00 ± 4.20	5754940522.57 ± 4.01
GC-HO	10953029513.05 ± 14.21	10953029534.40 ± 15.30	KK-UR	9052299802.60 ± 7.41	9052299802.55 ± 6.08
KA-KK	/	5709352430.49 ± 4.52	SH-TS	1829057095.42 ± 2.52	1829057093.79 ± 2.34
KA-HO	/	8071140229.19 ± 10.92	SH-UR	3249214224.17 ± 4.05	3249214225.27 ± 3.27
KK-HO	8268607668.19 ± 11.03	8268607648.98 ± 11.95	TS-UR	4434352022.77 ± 4.53	4434352019.17 ± 3.82
Mean of the relative uncertainty					
	1.215 × 10 ⁻⁹	1.094 × 10 ⁻⁹		0.880 × 10 ⁻⁹	0.854 × 10 ⁻⁹

Table 5. Rates of baseline lengths among VLBI stations in Asian-Pacific region

Baseline name	Length (km)	Nb of session	Time span (year)	Rate (mm/yr.)	S (mm/yr.)	wrms (mm)	Repeatability (10^{-9})
SH-GC	6636	41	88.04-98.11	-5.07	0.68	14.84	2.24
SH-KA	1876	31	88.04-97.10	-30.26	0.44	7.63	4.07
SH-KK	7310	20	93.06-98.12	-78.20	2.06	13.01	1.78
SH-HO	7965	22	89.12-98.11	-52.47	1.23	15.43	1.94
SH-UR	3249	13	94.03-98.12	-1.08	3.17	9.15	2.82
UR-GC	6728	13	94.03-98.11	-15.10	3.66	7.94	1.18
UR-KA	4485	6	95.04-97.10	-37.26	11.82	19.72	4.40
UR-KK	9052	10	94.03-98.12	-67.07	5.00	7.80	0.86
UR-HO	9860	4	94.10-98.11	-41.87	4.57	6.22	0.63
GC-KA	5427	176	84.07-98.08	1.90	0.20	11.46	2.11
GC-KK	4728	325	93.06-98.12	-44.47	0.23	6.25	1.32
GC-HO	10953	130	89.09-98.12	-37.68	0.82	25.73	2.34
KA-KK	5709	25	93.06-98.09	-60.06	1.12	8.37	1.47
KA-HO	8071	41	89.09-98.09	-46.90	1.34	18.55	2.30
KK-HO	8269	52	93.06-98.11	-41.06	1.93	15.34	1.86
Mean repeatability: 2.09×10^{-9}							

Table 6. Velocities of the VLBI stations in Asian-Pacific region

Site	Topocentric Velocity			Horizontal motion		Relative to NUVEL1A-NNR		Number of sessions
	Up	East	North	Rate (mm/yr)	Azimuth (deg.)	Rate (mm/yr)	Azimuth (deg.)	
	(mm/yr)							

SH	-0.13 ±0.60	30.40 ±0.20	-15.23 ±0.21	34.00 ±0.20	116.61 ±0.35	8.38 ±0.20	103.52 ±1.43	58
UR	-9.42 ±4.01	28.75 ±1.25	3.64 ±1.20	28.98 ±1.25	82.78 ±2.37	9.80 ±1.21	20.93 ±7.27	17
GC	0.38 ±0.09	-10.42 ±0.05	-21.10 ±0.05	23.53 ±0.05	206.28 ±0.12	0.95 ±0.05	181.07 ±3.03	1274
KA	-2.66 ±0.24	-5.40 ±0.10	-11.77 ±0.12	12.95 ±0.12	204.65 ±0.46	14.66 ±0.10	289.65 ±0.46	254
KK	-0.48 ±0.24	-64.79 ±0.10	33.43 ±0.12	72.91 ±0.10	297.29 ±0.09	6.55 ±0.10	279.85 ±1.05	473
HO	1.59 ±0.50	13.39 ±0.08	54.55 ±0.09	56.17 ±0.09	13.79 ±0.08	0.57 ±0.08	71.57 ±8.96	259

Fig. 1 VLBI measurements of the baseline from Seshan to Urumqi

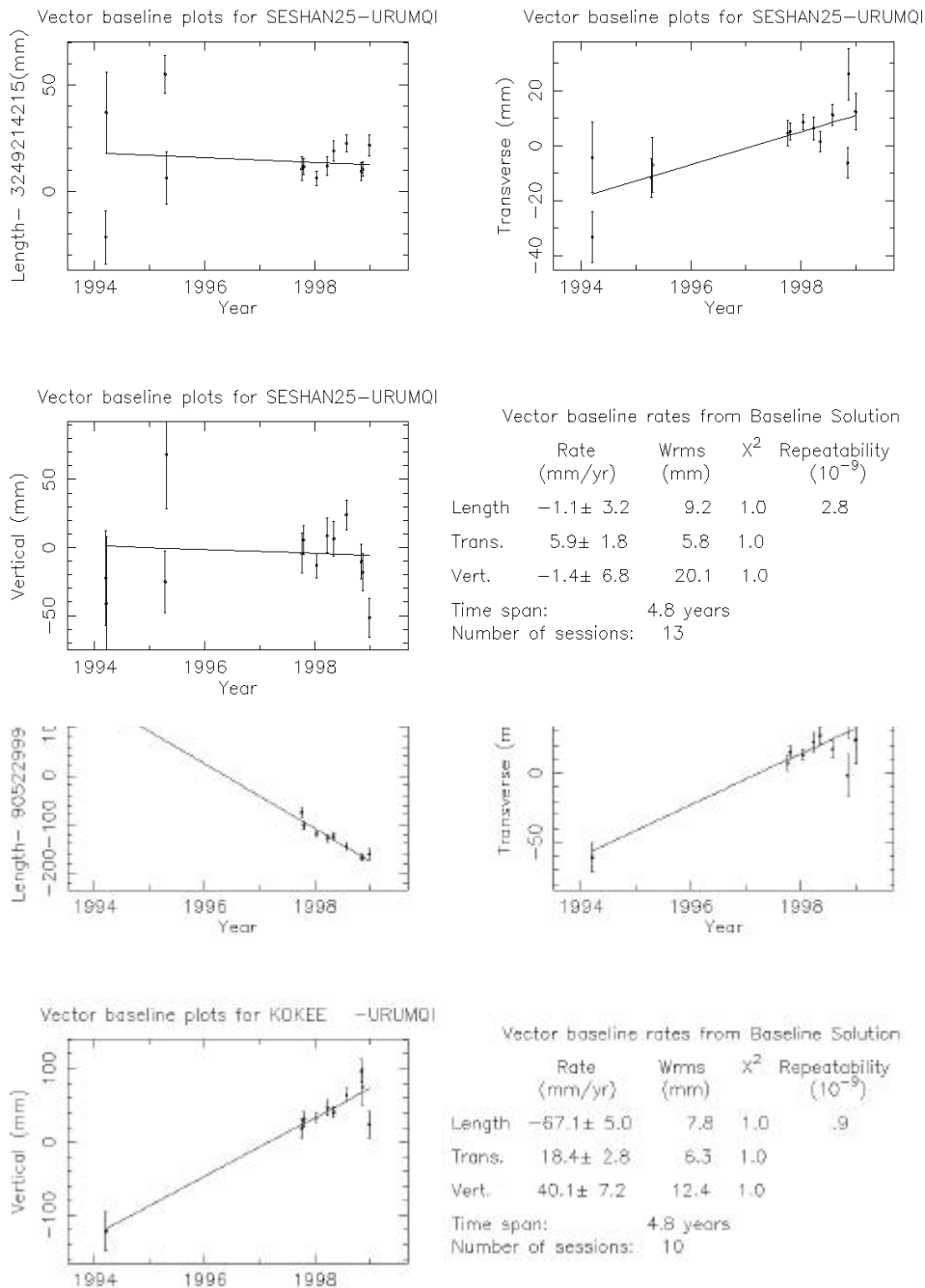


Fig. 3 VLBI measurements of the baseline from Hobart to Urumqi

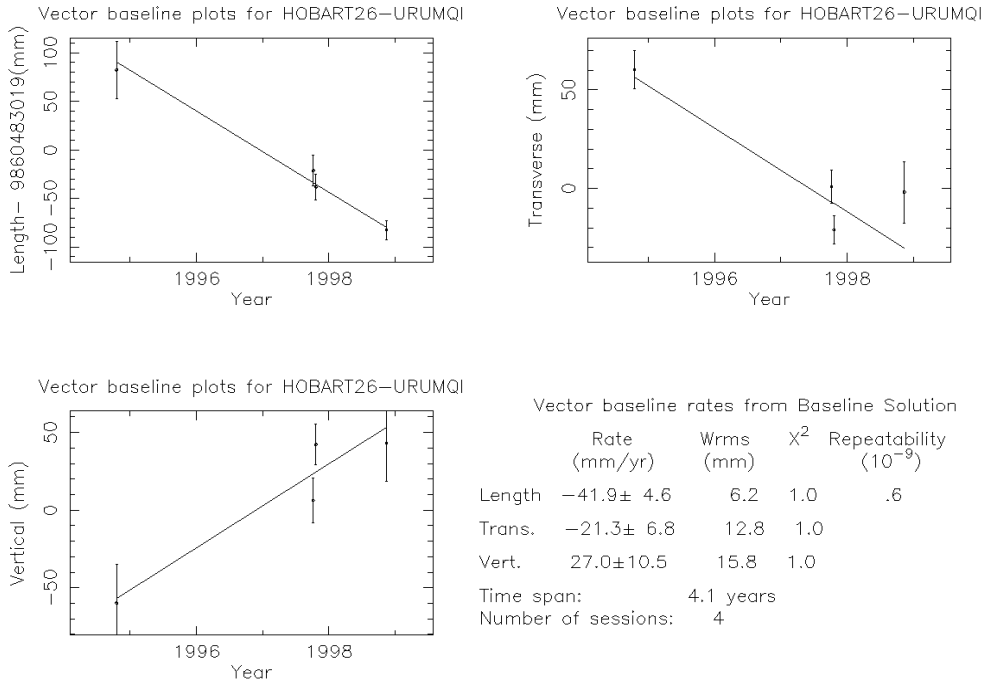


Fig. 4 VLBI measurements of the baseline from Hobart to Seshan

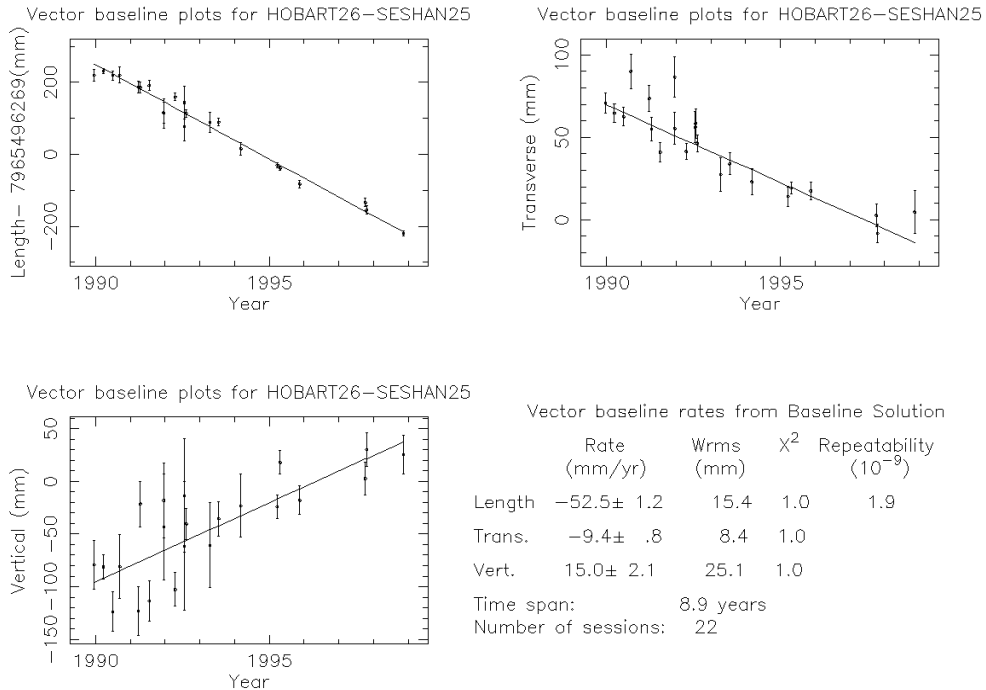


Fig. 5 VLBI measurements of the baseline from Gilcreek to Kokee

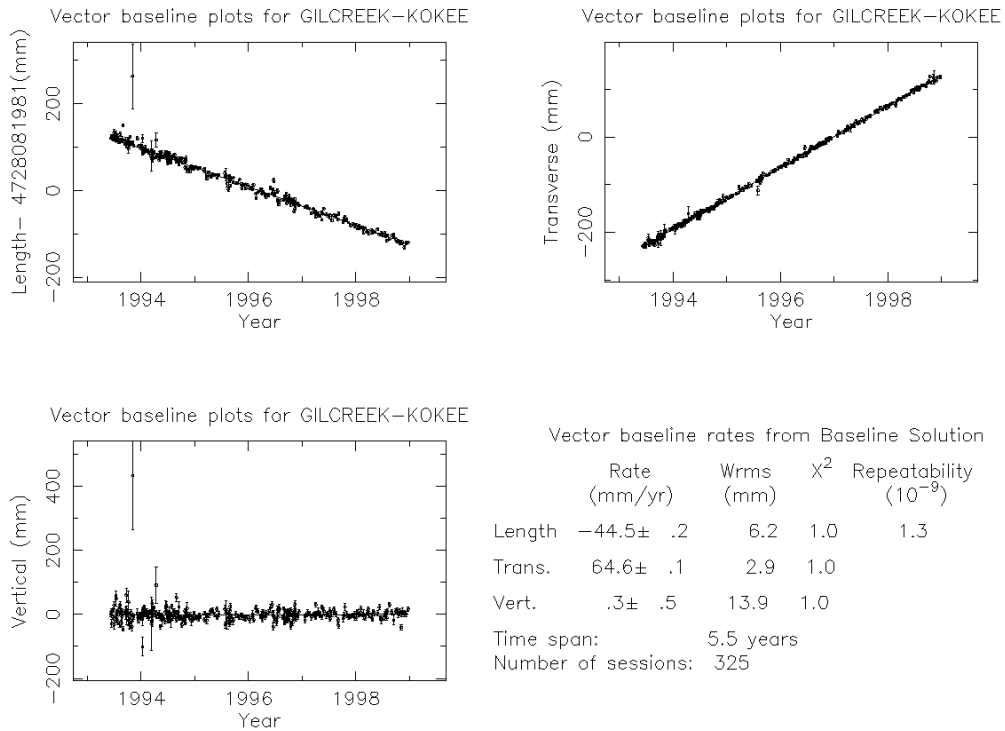
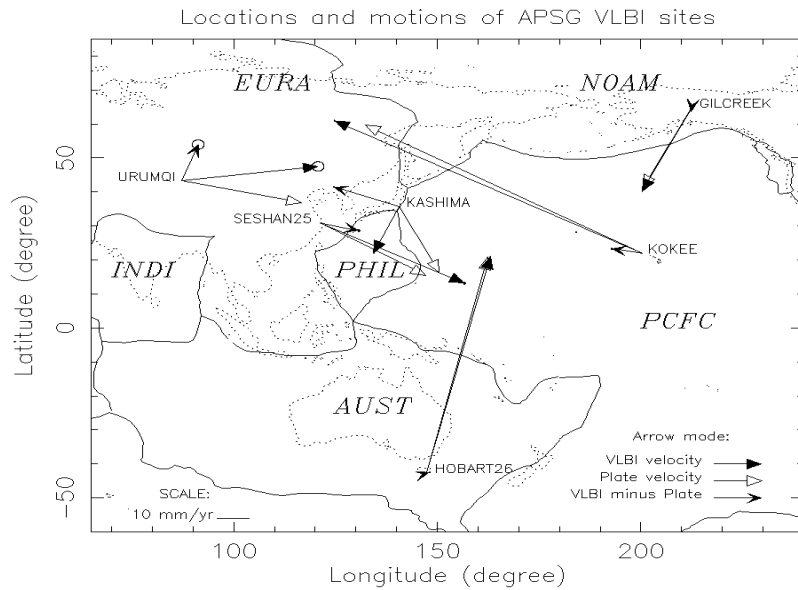


Fig. 6 VLBI measurements and plate motion model predictions of the motions at VLBI stations in the Asian-Pacific region.



Unification of Vertical Datums with Application to Asia and the Pacific

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Abstract

In general, neighbouring vertical datums can be compared directly at one or more common points on the border between the datums. This direct method requires levelling and gravity measurements. Such a direct connection is not possible if the datums are separated by an ocean or another body of water. Then a rigorous mathematical model, an indirect approach, may be useful. In order to connect regional vertical datums, a rigorous mathematical model is derived based on a method by Rummel and Teunissen. In this study, vertical datums are connected indirectly by means of a combination of precise geocentric positions of tide gauge sites and their geoid heights in one geocentric coordinate system and their height values in the respective height datums.

keywords. vertical datums, modified Stokes formula, geoid, GPS, gravity

1 Introduction

There are many regional vertical datums in the world which are, in most cases, based on averaging tide gauge readings at one or more primary tide gauges over some period to define a Mean Sea Level (MSL) surface as a local vertical datum. The deviation of the MSL from the geoid is of the order of ± 2 m globally (Rapp and Balasubramania, 1992), which shows the inconsistency of the various height systems that are based on fixing tide gauges.

The other problem is the temporal changes in the annual MSL of the order of 1-2 mm with a general trend of 150 to 200 mm per century (see Rummel and Teunissen, 1988). Also, there are some lateral variations of MSL among tide gauges (e.g. from salinity, wind pressure, currents), which can pose deviations of MSL from one common equipotential surface in a small area and in addition vary from year to year (Rummel and Teunissen, 1988).

A problem that must also be considered in this context is that many vertical datums are based not only on one fundamental benchmark, but on the MSL estimated at several tide gauges. As the MSL is not an equipotential surface, the definition of a vertical datum as the MSL at more than one tide gauge inevitably implies a forced deformation of the network. We will not consider this type of definition of height networks in our study, but assume that the networks are either defined by the MSL at one benchmark or by the mean of the MSL at several tide gauges.

In general, there is no problem to connect two adjacent vertical datums, i.e. provided the

potential or height values of two benchmarks in the two systems are known, they can be connected, directly, by levelling and gravity measurements. Such a direct connection is not possible if the vertical datums are separated by an ocean, for example. Another way to connect vertical datums based on a rigorous mathematical model, called indirect approach, was developed by Rummel and Teunissen (1988). This method can only be used indirectly by means of a combination of precise geocentric positions of tide gauge sites and their geoid heights in one geocentric coordinate system and their height values in the respective height datums.

As an example, the Finnish and the Swedish height systems are already connected directly by levelling and gravity measurements. Sjöberg (1991a) directly compared the height differences between the systems at some connecting levelling benchmarks north of the Bay of Bothnia, and found that the difference is -19.2 cm. Ekman (1992) compared the two height systems in a similar way, but added two reductions to the Swedish height system RH70 (for geoid surface and epoch). He found a difference of -16.2 cm. Pan and Sjöberg (1998) investigated an indirect rigorous mathematical model based on Stokes formula similar to Rummel and Teunissen (1988). Their numerical applications utilized three approaches: the rigorous approach, a bias fit and a 3-parameter fit. The results between the Swedish RH70 and the Finnish N60 height systems were estimated to -19.3 ± 6.5 cm, -17 ± 6 cm and -15 ± 6 cm, respectively, for the three approaches. These computations included the reductions suggested by Ekman (1992). Nahavandchi and Sjöberg (1998) improved an indirect approach based on GPS and gravimetric geoid models using the modified Stokes formula. They also studied the accuracy of potential differences estimated from several observed points in each network.

2 Unification of vertical datums - The observation equation

The geoid undulation N can be computed from the following well-known formula (Heiskanen and Moritz, 1967):

$$N = h - H \quad (1)$$

where h is the ellipsoidal height, and H is the orthometric height. Let O be a point at sea level and P be another point, connected to O by levelling (see Figure 1). The orthometric height of point P is given by (Heiskanen and Moritz, 1967):

$$H = \frac{C_{PO}}{\bar{g}} \quad (2)$$

where \bar{g} is the mean value of gravity along the plumb line between sea level and P , and C_{PO} is the potential differences computed from (Heiskanen and Moritz, 1967):

$$C_{PO} = C(P, O) = W(O) - W(P) = \int_O^P g dH \quad (3)$$

where g is gravity and W is gravity potential.

Equation (3) can now be rewritten for any regional vertical datum passing through a point P_i (see Figure 1):

$$C_{P_iO} = W(O) - W(P_i) \quad (4)$$

The separation between the regional equipotential surface and the reference ellipsoid can be written (see Rummel and Teunissen, 1988) (see Figure 1)

$$N^i(P) = N_0 + \frac{C_{P_iO}}{g} + \frac{R}{4pg} \sum_{j=1}^n \iint_{\Delta s_j} S(\mathbf{y}) \left(\Delta g^j + \frac{2}{R} C_{P_iO} \right) d\mathbf{s}, \quad (5)$$

where the upper index (i) of N expresses the fact that P lies in the datum zone with datum point P_i and refers to the i -th regional vertical datum, $j=1, 2, \dots, n$ being the number of regional vertical datums, Δg^j is the observed gravity anomaly, which is reduced to the level surface passing through P_i , g is the normal gravity on the reference ellipsoid, R is the mean radius of the Earth, \mathbf{y} is the spherical distance between the computation and running points, $S(\mathbf{y})$ is Stokes function, Δs_j is the solid angle of datum zone j and the constant N_0 is

$$N_0 = -\frac{\Delta W_0}{g} + \frac{GdM}{Rg}, \quad (6)$$

where G is the gravitational constant, ΔW_0 is the difference between the constant gravity potential at the geoid and constant normal potential at the reference ellipsoid and dM is the difference between the mass of the Earth and the mass of the ellipsoid. However GM is known rather well. Ries et al. (1992) estimated it to unprecedented accuracy from a recent solution which utilized data acquired on Lageos, Starlette and Ajisai, and included background modeling of general relativistic effects, yielding a value of $398600.4415 \pm 0.0008 \frac{km^3}{s^2}$. Therefore we will regard GM as known in the sequel ($GdM = 0$).

As the modified Stokes formula will be used in our study, Eq. (5) is modified as (see for example Sjöberg, 1986; Vaníček and Kleusberg, 1987; Vaníček and Sjöberg, 1991):

$$N^i = N_0 + \frac{C_{P_iO}}{g} + \frac{R}{4pg} \sum_{j=1}^n \iint_{\Delta s_j} S_{l+1}^M(\mathbf{y}) \left(\Delta \hat{g}^j + \frac{2}{R} C_{P_iO} \right) d\mathbf{s} + \frac{R}{2g} \sum_{n=2}^l s_n \Delta \hat{g}_n, \quad (7)$$

where $S_{l+1}^M(\mathbf{y})$ is the modified spheroidal Stokes function expressed by:

$$S_{l+1}^M(\mathbf{y}) = S_{l+1}(\mathbf{y}) - \sum_{i=0}^M \frac{2n+1}{2} s_i P_i(\cos \mathbf{y}), \quad (8)$$

and S_{l+1} is spheroidal Stokes function as

$$S_{l+1}(\mathbf{y}) = \sum_{k=l+1}^{\infty} \frac{2k+1}{k-1} P_k(\cos \mathbf{y}), \quad (9)$$

where the reference spheroid is given by spherical harmonic functions up to degree and order l . Here, the degree of reference spheroid is considered the same as the maximum degree of modification (i.e. $l = M$). In the above formulas $\Delta\hat{g} = \Delta g - \sum_{n=2}^l \Delta\hat{g}_n$, where Δg is observed gravity anomaly, $\Delta\hat{g}_n$ is from geopotential model estimated gravity anomaly Laplace harmonic of degree n and $P_n(\cos\gamma)$ is Legendre's polynomials. There are different procedures to determine s_i coefficients, each of which is related with some criterion for the modification; for example the least squares method (Sjöberg, 1986 and 1991b),

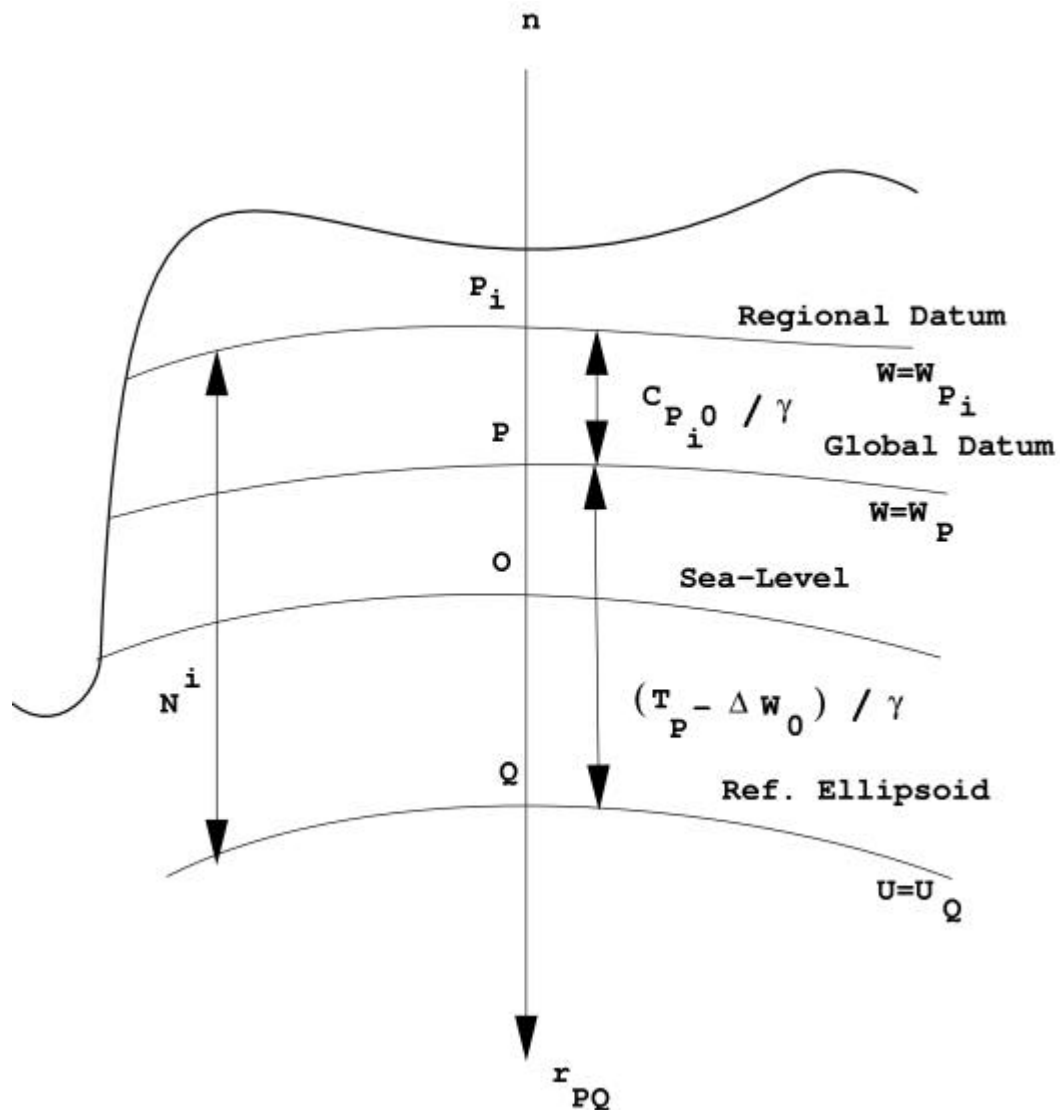


Figure 1: Separation between the regional and global equipotential surfaces and the reference ellipsoid

Vincent and Marsh (1974) method, modified spectral weighting (Sjöberg, 1980; Wenzel, 1982) and Molodenskij et al. (1960) method. Using Molodenskij's method the s_i coefficients can be expressed from the system of linear equations (Molodenskij et al., 1960):

$$\sum_{k=0}^l (2k+1)e_{ik}(\mathbf{y}_0)s_k = 2Q_i^l(\mathbf{y}_0) \quad \forall i. \quad (10)$$

Here

$$e_{ik}(\mathbf{y}_0) = \int_{\mathbf{y}=\mathbf{y}_0}^p P_i(\cos \mathbf{y}) P_k(\cos \mathbf{y}) \sin \mathbf{y} d\mathbf{y}, \quad (11)$$

and

$$Q_i^l(\mathbf{y}_0) = Q_i(\mathbf{y}_0) - \sum_{j=2}^l \frac{2j+1}{j-1} e_{ij}(\mathbf{y}_0), \quad (12)$$

where

$$Q_i(\mathbf{y}_0) = \int_{\mathbf{y}=\mathbf{y}_0}^p S(\mathbf{y}) P_i(\cos \mathbf{y}) \sin \mathbf{y} d\mathbf{y} \quad (13)$$

are the Molodenskij truncation coefficients. In the above mentioned modified Stokes formula, the long and medium wavelength components of the geoid are determined from earth gravity models, whereas the short wavelength contributions are obtained from terrestrial gravity information.

At each tide gauge station, the geoidal height N^i , referred to the regional vertical datum passing through P_i , can be computed also directly from GPS/levelling by the formula

$$N^i = h - H^i. \quad (14)$$

The upper index (i) indicates again that N and H belong to the local vertical zone i , i.e. they refer to a level surface passing through P_i . N^i of Eq. (14), derived from the orthometric height in combination with h from space methods, can now be compared with the corresponding gravimetrically determined N^i of Eq. (7). At each of the tide gauge stations, we can write

$$N^i = h - H^i = N_0 + \frac{C_{P_i O}}{g} + \frac{R}{4pg} \times \sum_{j=1}^n \iint_{\Delta S_j} S_{l+1}^M(\mathbf{y}) (\Delta \hat{g}^j + \frac{2}{R} C_{P_j O}) d\mathbf{s} + \frac{R}{2g} \sum_{n=2}^l S_n \Delta \hat{g}_n. \quad (15)$$

Now the following observation equation for the unknowns N_0 and $C_{P_j O}$ ($j = 1, 2, \dots, n$) can be established as:

$$y_i = N_0 + \frac{C_{P_i O}}{g} + \frac{R}{4pg} \sum_{j=1}^n \iint_{\Delta S_j} S_{l+1}^M(\mathbf{y}) \frac{2}{R} C_{P_j O} d\mathbf{s}, \quad (16)$$

where the observations are given by

$$y_i = h - H^i - \frac{R}{4pg} \sum_{j=1}^n \iint_{\Delta s_j} S_{l+1}^M(\mathbf{y}) \Delta \hat{g}^j d\mathbf{s} - \frac{R}{2g} \sum_{n=2}^l s_n \Delta \hat{g}_n; \quad (17)$$

For a large number n (= No. of observations y_i) $\geq n+1$, in practice globally distributed over the datum zones, we may determine all the unknowns, including N_0 . From a regional data set we can only estimate a few datum zone parameters (C_{P_jO}). Now, let us take a closer look at the integral (16). Each unknown C_{P_jO} can be taken as a constant value inside each datum zone, yielding

$$\frac{1}{2pg} \sum_{j=1}^n \iint_{\Delta s_j} S_{l+1}^M(\mathbf{y}) C_{P_jO} d\mathbf{s} = \frac{1}{2pg} \sum_{j=1}^n C_{P_jO} \iint_{\Delta s_j} S_{l+1}^M(\mathbf{y}) d\mathbf{s}. \quad (18)$$

The modified spheroidal Stokes kernel can be approximated by the following linear form:

$$\tilde{S}_{l+1}^M(\mathbf{y}, \mathbf{y}_0) = \mathbf{b}_0 + \frac{\mathbf{b}_1}{\mathbf{y}} + \mathbf{b}_2 \ln\left(\frac{\mathbf{y}}{2}\right) + \mathbf{b}_3 \mathbf{y}^2 \ln\left(\frac{\mathbf{y}}{2}\right). \quad (19)$$

Here, the coefficients are function of \mathbf{y}_0 and are selected in such way as to make \tilde{S}_{l+1}^M fit the modified kernel S_{l+1}^M as well as possible in the uniform (Tchebyshev) sense. The selection has been done approximately by moving the four needed Tchebyshev interpolation nodes until a good fit has been achieved. The resulting approximate function for $l = M = 20$ becomes

$$\tilde{S}_{l+1}^M(\mathbf{y}) = -32.435 + \frac{2}{\mathbf{y}} - 3.449 \ln\left(\frac{\mathbf{y}}{2}\right) - 173.24 \mathbf{y}^2 \ln\left(\frac{\mathbf{y}}{2}\right). \quad (20)$$

This approximation yields a maximum relative error better than 10^{-3} for an integration radius of 6 degrees (Vaníček and Kleusberg, 1987).

Using the notation

$$A_{k_j} = \frac{1}{2p} \iint_{\Delta s_j} \tilde{S}_{l+1}^M(\mathbf{y}) d\mathbf{s}, \quad (21)$$

for the integral in (21) determined at the arbitrary point P_k and Eq. (18), we get from Eq. (16) (see also Rummel and Teunissen, 1988)

$$y_k = -N_0 + \frac{C_{P_iO}}{g} + \sum_{j=1}^n \frac{C_{P_jO}}{g} A_{k_j} = -N_0 + \left[1 + A_{k_i}\right] \frac{C_{P_iO}}{g} + \sum_{j=1(j \neq i)}^n A_{k_j} \frac{C_{P_jO}}{g}, \quad (22)$$

where A_{k_i} and A_{k_j} are the integrals (21) over the datum zone i and j respectively.

Here, for the sake of simplicity, we have approximated the modified spheroidal Stokes

function by the linear form of Eq. (20), which applies to the modifying parameters s_n determined by Eq. (10) for $l = M = 20$. According to our computations (see also Pan and Sjöberg, 1998), the coefficients A_{k_j} are much less than one. In such a case all terms with these parameters in Eq. (22) are very small numbers and can therefore be neglected without loss of accuracy. Also, replacing S_{l+1}^M by the approximate function \tilde{S}_{l+1}^M , saves the computation labour without degrading the accuracy.

It should be here mentioned that different countries use different ways to deal with their levelling reductions, e.g., in handling the permanent tide. Therefore, height and gravity systems for the countries in question must be analysed, separately. It should be clear whether normal heights have been used or orthometric heights and so on. Either the height system referred to the non-tidal geoid (which permanent tide has been omitted) or mean geoid.

Conclusions

The connection of two neighbouring vertical datums poses no particular problem, as long as the reference values of the fundamental benchmarks are known and the potential (or height) differences between them can be measured. Problems start with the unification of vertical datums on a continental scale, when for example those are separated by an ocean. The problem can be solved indirectly from a combination of levelled potential (or height) differences and geoid computation gravimetrically, and independently, by a combination of precise satellite positioning and orthometric (or normal) heights of the respective datum.

Then a rigorous indirect method based on gravimetric and GPS/levelling determination of geoidal undulation was developed. We have used the modified Stokes formula.

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The status of vietnam geodetic network and a proposal for indochina region

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I. INTRODUCTION

Over the last 100 years, National Geographic Institute of France established the first geodetic control network which was covering whole territories of Indo-China. It was a conventional triangulation network in which the distance base lines and Laplace's azimuths are distributed with the density about 200 km each one, horizontal angles have 1" accuracy. The reference system was selected as follows:

- Reference Ellipsoid: Clacke,
- Grid Projection: Bonne,
- Fixed point: Hanoi Tower.

From the establishment time up to 1954, this geodetic network was used to topographic mapping at the scale 1/100,000 covering whole Indo-China and at large scales for some important areas.

During 1954 – 1975, geodetic network in the North of Vietnam was set up as 1st and 2nd order triangulation with a good enough accuracy. The old 1/100,000 topographic maps were upgraded into the new geodetic co-ordinates system. The reference system for the North of Vietnam was decided as follows:

- Reference Ellipsoid: Krasovski,
- Grid Projection: Gauss,
- Fixed point: Punkovo (SU).

In the South of Vietnam, from 1954 to 1975, the basic survey - mapping works were done by the Defense Mapping Agency (DMA) of US. The DMA concentrated mainly on the topographic map system at the scale 1/50,000 covering whole the Indo-China and Thailand based on aerial-satellite images stereo-plotting. The reference system for the South of Vietnam was defined as follows:

- Reference Ellipsoid: Everest,
- Grid Projection: UTM,
- Fixed point: according to the Indian datum.

From 1975, the State Department of Survey and Mapping (SDSM) had the plan to extend the national geodetic network to cover the South of Vietnam. During 1977 – 1989, the SDSM completed the geodetic network by triangulation and traverse of 2nd order covering 70% of the South of Vietnam except Tay Nguyen Plateau, Song Be rubber forest and Minh Hai marsh. In the period 1990 - 1994, the geodetic network of Vietnam was completed by using the GPS technology. After that the long distance GPS geodetic network was also completed covering throughout the sea territory of Vietnam and up to 1998 measurement of the national geodetic network was finished. Since 1994 the General Department of Land Administration has been focusing on renovation of the national geodetic network basing on following ideas:

- setting up a high accuracy “0 - order” geodetic network covering whole country which is connected to international and regional geodetic networks;
- selection of a new reference system oriented to world system;
- establishment of precise geoid model;
- integrated adjustment of national control network.

In 1999 the new reference system of Vietnam has been decided as follows:

- | | |
|------------------------|---------|
| ▪ Reference Ellipsoid: | WGS-84, |
| ▪ Grid Projection: | UTM, |
| ▪ Fixed point: | Hanoi. |

II. ACCURACY OF THE GEODETIC NETWORK OF VIETNAM

The Conventional National Geodetic Control Network of Vietnam has different types of networks such as triangulation of 1st and 2nd order, traverse of 2nd order, short distance GPS. This network has a lot of kinds of measurement: horizontal and vertical angles, directions, distances, azimuths, astronomical longitudes and latitudes, single frequency static GPS. The triangulation of 1st order covers only the North of Vietnam with the density about 150Km² per point. The triangulation of 2nd order covers the North and coastal zone of the Center of Vietnam with the density about 100Km² per point The Mekong delta is covered by traverse of 2nd order which has the density about 30Km² per point The single frequency GPS was established for Tay Nguyen, Minh Hai and Song Be areas with the density about 250Km² per point

After completion of the conventional geodetic networks the long distance GPS network with high accuracy was implemented on the basis of application of the dual frequency GPS. This geodetic network named “0”-order network covers throughout the land and sea territories of Vietnam. In this network the shortest distance is 80Km and longest one is 1,800Km.

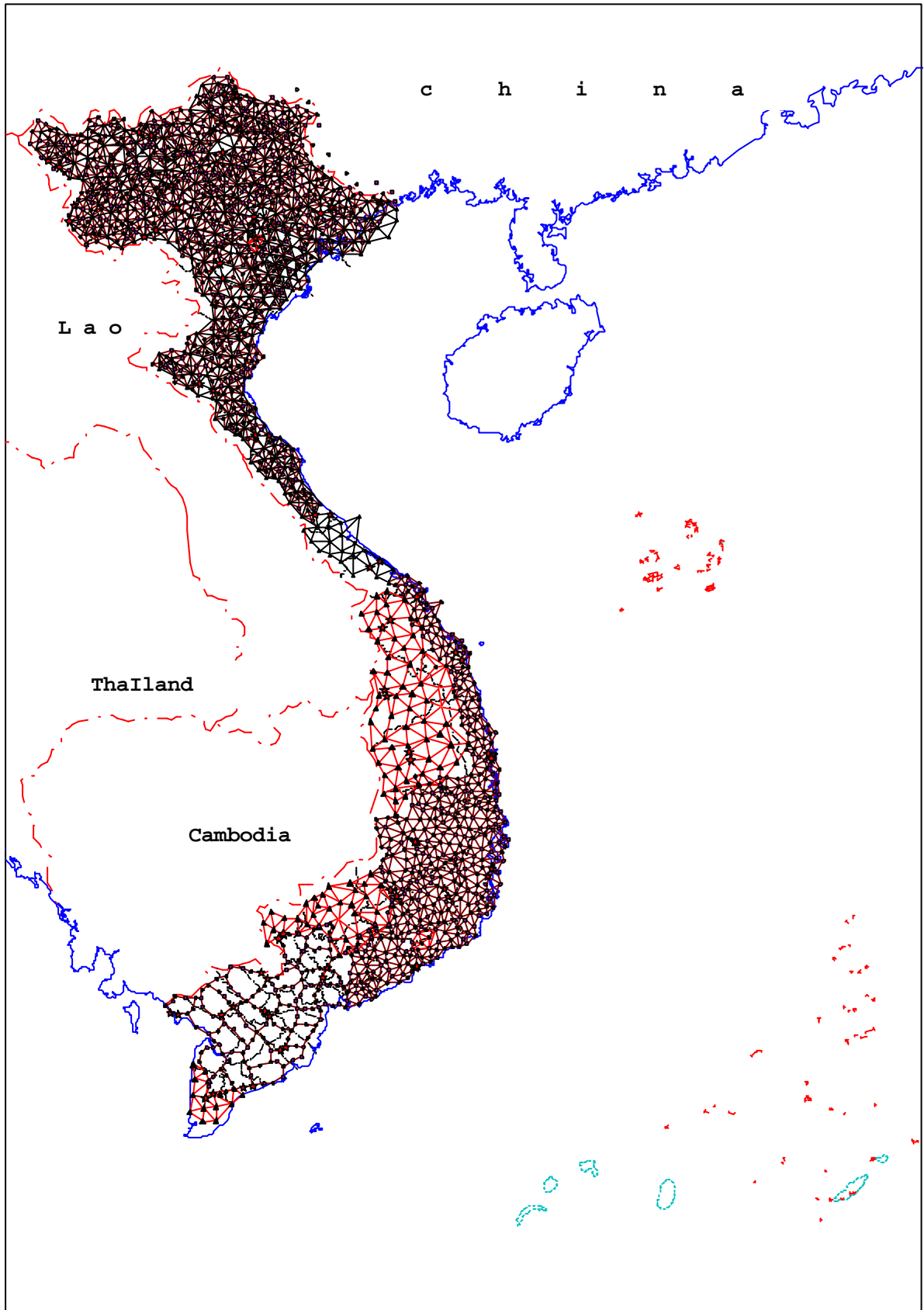
After adjustment and accuracy analysis of the sub-networks the results are described within the following tables:

Table 1: The accuracy of the conventional measurements in Vietnam geodetic network

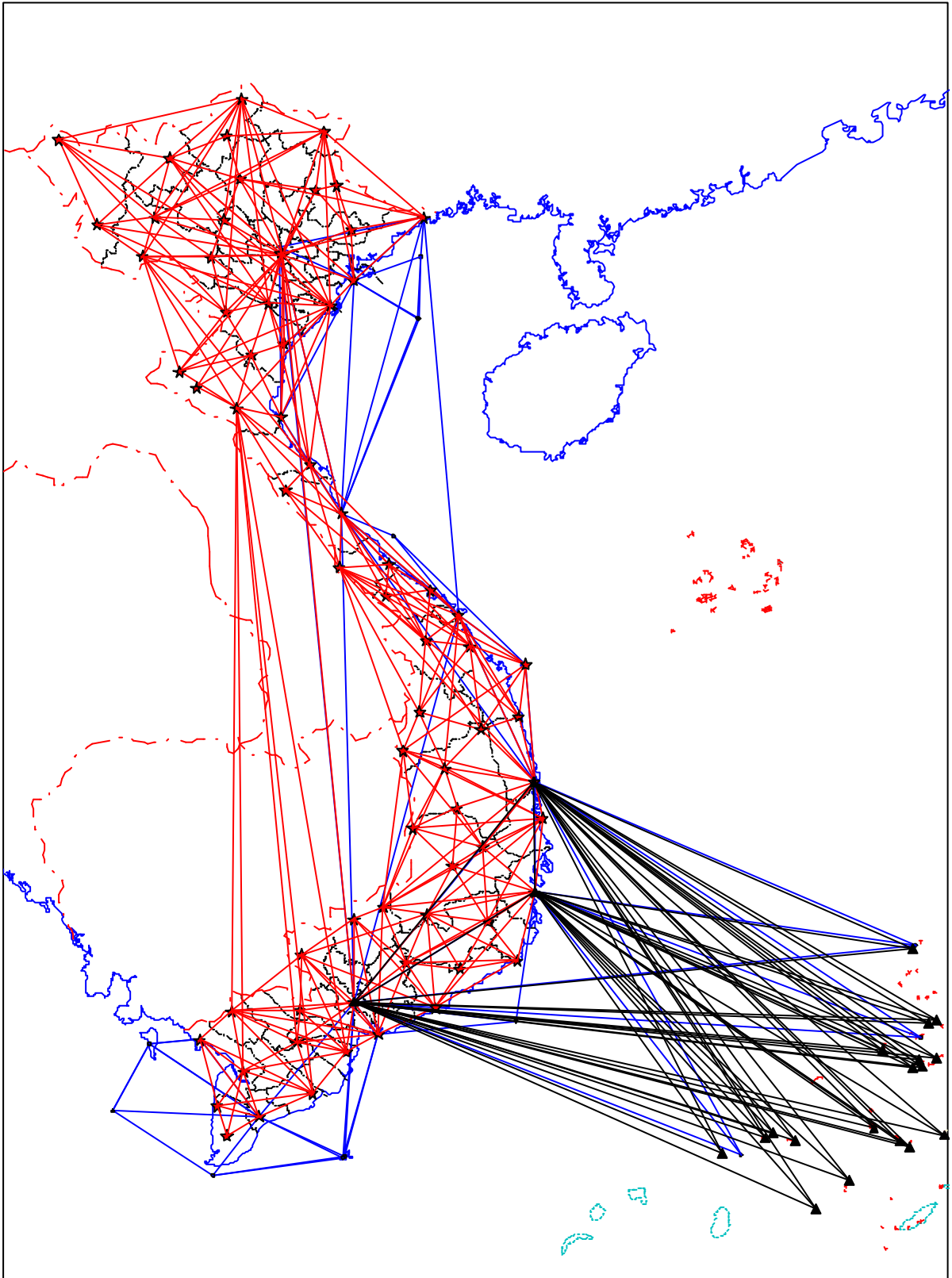
NETWORK	DISTANCE	HORIZONTAL ANGLE	AZIMUTH
TRIANGULATION OF I ORDER	1/370000	0"65	0"55
TRIANGULATION OF II ORDER IN THE NORTH	-	0"90	-
TRIANGULATION OF II ORDER IN THE CENTER	1/220000	1"00	0"45
TRAVERSE OF II ORDER	1/200000	1"10	0"45
SINGLE FREQUENCY GPS	1/15200000		0"015
DUAL FREQUENCY GPS	1/9000000		0"004

Table 2: The accuracy of the adjusted elements in the Vietnam geodetic network

ELEMENTS		RMS _{min}	RMS _{max}
GPS DUAL FREQUENCY S > 300 Km	M _{S/S}	1/600,000,000	1/42,000,000
	M _α	0"001	0"010
	M _{ΔH}	0.001m	0.015 m
GPS DUAL FREQUENCY 300 Km > S > 40 Km	M _{S/S}	1/1,500,000,000	1/1,500,000
	M _α	0"001	0"016
	M _{ΔH}	0.0002 m	0.095 m
GPS SINGLE FREQUENCY 300 Km > S > 40 Km	M _{S/S}	1/650,000,000	1/580,000
	M _α	0"001	0"320
	M _{ΔH}	0.0001 m	0.099 m
DISTANCE BASE OF I & II ORDER TRIANGULATION	M _{S/S}	1/910,000	1/290,000
LAPLACE's AZIMUTH	M _α	0"150	0"360
TRIANGULATION OF I ORDER	M _{S/S}	1/1,450,000	1/235,000
	M _α	0"14	0"61
TRIANGULATION OF II ORDER	M _{S/S}	1/980,000	1/124,000
	M _α	0"22	1"23
TRAVERSE	M _{S/S}	1/328,000	1/124,000
	M _α	0"27	0"94



Triangulation Traverse and GPS networks of I & II order



“0” order and Islands geodetic networks

III. BRIEF DESCRIPTION OF ADJUSTMENT OF VIETNAM ASTRONOMIC - GEODETIC - SATELLITE NETWORK

1. Data Set

From 1959 to 1997 Vietnam has an Astronomic - Geodetic- Satellite Network covering whole country. This Network includes the following observations (see table 3):

Table 3: Observations of the Astronomic - Geodetic- Satellite Network of Vietnam

No	Type of Network		Number	Remark	
1	Triangulation of I order	Point	339	Terrestrial Observations	
		Angle	1450		
2	Triangulation of II order	Point	1111		
		Angle	6251		
3	Traverse of II order	Point	174		
		Angle	234		
		Distance	195		
4	Distance Base		23		
5	Laplace's Azimuth		29		Astronomic Observations
6	Astronomic Point		66		
7	Doppler	Point	19	Satellite Observations	
		Baseline	33		
8	GPS Dual Frequency	Point	71		
		Baseline	281		
9	GPS Single Frequency	Point	123		
		Baseline	298		
10	GPS single point with 24 hour observation		8		
11	GPS points having Geoid height		367		

2. Definition of the World Geodetic Coordinates for the Local Network

The World Geodetic Coordinates are needed for adjustment of Vietnam Astronomic - Geodetic - Satellite Network. For the first these coordinates are used to GPS baseline processing, and for the second they will give us a tool to connect the local geodetic network to the World Geodetic Reference System. For this purpose 8 points of the GPS dual frequency network have been selected for 24 hour GPS observation. Using the Pseudo-Range Processing software we have the World Geodetic Coordinates of these 8 points with accuracy about 1 meter. From the other side, based on the IGS observations at the same time we can formulate a network between our 8 points and some IGS points in this region. This network includes 8 points of the local network and 4 points of IGS Network (Lhasa, Shao, Guam, Taiwan). After this network adjustment we have the accuracy as follows:

- m_s/S : 1/20,000,000 - 1/145,000,000

- m_{α} : 0"001 - 0"050
- m_H : 0.015 m - 0.160 m
- m_P : 0.080 m - 0.136 m

3. Definition of Geoid Model

The Geoid Model for Vietnam area has been defined by two ways: the first solution is application of the astronomic - geodetic - gravimetric interpolation based on 66 astronomic points and gravimetric data, the second solution is application of the collocation interpolation of Geoid height based on 367 GPS points which have levelling elevation. The received Geoid Model has Geoid height accuracy about 0.8 meter. It is good enough for reduction of terrestrial observations to the World Geodetic Reference System.

In near future we have plan to make a higher accuracy Geoid Model (about 1 dm) for Vietnam area. Up to 2002 the National Cadastral Network including about 20,000 GPS points covering whole country will be completed in which about 1,000 GPS points are connected to the levelling network. The GPS - levelling data will be processed together with gravimetric data. This Geoid Model, of course should be used to GPS levelling technique.

4. Network Adjustment

The Vietnam Terrestrial - GPS network has been adjusted by 3 softwares: Trimble Trimnet+ and 2 domestic ones. each of these softwares has the following functions:

- Analyst of observations and elimination of low quality measurements;
- Estimation of measurement weight;
- Adjustment of GPS and terrestrial observations;
- Definition of network accuracy.

The results from this adjustment by 3 softwares have been identical. This is the best way for quality control of network adjustment.

IV. A PROPOSAL FOR THE INDO-CHINA GEODETIC NETWORK

About a century ago French established a triangulation network covering whole Indo-China. This network had very important role in survey and mapping works in this area. Based on this geodetic network the Toographic Maps System at the scale 1/100,000 was produced. Since 1954 the Defence Mapping Agency of US used this geodetic network to production of the Toographic Maps System at the scale 1/50,000 covering whole Indo-China and Thailand.

In current time Vietnam Government has some technical assistances for Laos in survey and mapping field. The territory of Laos was covered by the long distance GPS in 1992 with the total 25 points. In the delta of Vientiane and the South of Laos there are 57 points of short distance GPS network. Laos has participated in the APRGP98 with 7 points.

Up to now Cambodia has no any modern geodetic network excluding the network

established by France before. Cambodia in present time has 6 stand alone points only in the APRGP98 campaign.

In 1998 Vietnam participated in the APRGP98 campaign with 4 GPS points.

Considering the density of GPS points in the regional geodetic network for Asia and the Pacific, we can have some following comments:

- The Asia and the Pacific Geodetic Network would be designed to fulfill the following functions:
 - It is the basic component of the GIS infrastructure.
 - It is the control points to research the activities of the Earth's crust and sea level in wide areas.
 - It is the tool for survey and mapping data exchange between countries to set up global / regional map systems.
 - It is the way to develop DGPS technology for developing countries.
- In present time the density of the Regional Geodetic Points is not regular. It is very low in some areas such as India, China, Russia and the Pacific, and very in some areas such as Malaysia, Indo-China. In the future we need more discussions on design of a reasonable form of the Asia and the Pacific Geodetic Network.
- Every country has own geodetic network. The countries located in the same geological zone should take discussion on a joint selection of some GPS sites for the Asia and the Pacific Geodetic Network, and some GPS sites for a sub-regional geodetic network of these countries. By this way we will have a good networks for research of modern tectonics of the Earth's crust.

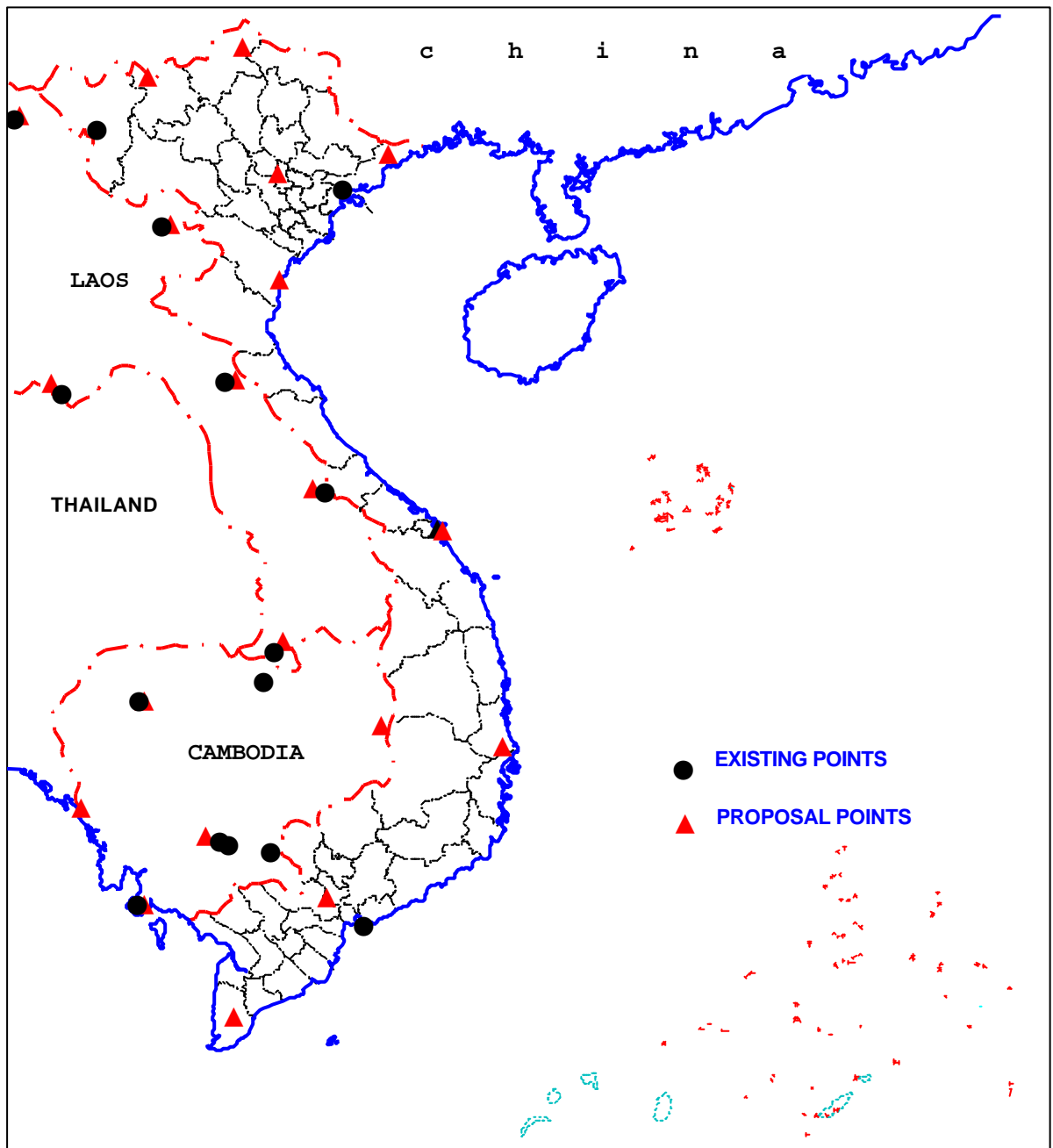
Based on the said above comments we would like to have a proposal for design of the Indo-China Sub-regional Geodetic Network and Indo-China GPS sites for APRGP99. As known before Vietnam and Laos and Cambodia have 17 GPS points participated in APRGP98, in which some points in the boundary of countries are too closed.

The Indo-China Peninsula is located in the area which is divided by Mekong River and Red River. To research modern tectonics of the Earth's crust in this area we need a high precision geodetic network covering whole Indo-China. GPS observations will be made at all these points at the same time of APRGP99 carrying out. In farther future the points of the Indo-China Geodetic Network should be the GPS permanent points of each country.

The proposal on the Indo-China Geodetic Network design is as follows:

1. The Network including 21 GPS points, in which 2 points in the East of the Red River (Vietnam), 2 points at the Red River bank (Vietnam), 4 points in the West of the Mekong River (1 in Vietnam, 1 in Laos, 2 in Cambodia), 4 points at the Mekong River bank (1 in Vietnam, 2 in Laos, 1 in Cambodia), 9 points located between the Red River and Mekong River (4 in Vietnam, 1 in Cambodia, 4 in Laos).
2. All the points of Indo-China Geodetic Network should be participated in the Asia and the Pacific Regional Network.
3. The points of Indo-China Geodetic Network will be the GPS permanent points of each country in farther future.
4. The points of Indo-China Geodetic Network fulfill the role of basic points for the

National Geodetic Network of each country.



proposal for the indo-china geodetic network

V. CONCLUSION

Overall, from this report we would like to supply some information about the National Geodetic Network of Vietnam. After that we try to put forward a discussion on a proposal of establishment of the Indo-China Geodetic Network. It is a part of the Asia and the Pacific Regional Network. This idea is a proposed activities for long term implementation, based on possible agreement between Cambodia and Laos and Vietnam.

Surveying and Mapping Activities of Nepal

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Background Information:

The kingdom of Nepal is located in south Asia. The country is landlocked by Tibet (Autonomous region of China) in the North. East, West, and South lie the border of India. The natural phenomenon of the continental shift has revealed this zone in intense compression centered along the Himalayan arc. This makes the study of Geodynamics in this part of the globe interesting and challenging.

The total land area of the country is 147,181sq. Km stretching about 885 km in length from East to West and between 145 km to 241 in the width in the north-south direction. The intense variation in the height in the small change in the latitude gives rise to the wide variation in the topographic built up of the country resulting the existence of different climatic zones. The variation in the height can be observed from 60 m to 8,848 m in 1.6 degree change in the latitude.

From the topographic point of view country can be divided into five physiographic regions and country offers different climates such as subtropical, temperate, sub-alpine, and alpine types depending in the altitude variation.

The area coverage and average altitude of the five physiographic regions are given below:

Area	Altitude	Area in %
1. Southern Terai Plains	60 - 330 m	14.3
2. Siwalik Hills	200 - 1500 m	12.8
3. Middle Mountains	800 - 2400 m	30.1
4. High Mountains	2200 - 4000 m	20.1
5. High Himalayas	> 4000 m	22.7

Himalayas in the northern part of the country belong to the active tectonic areas of the world. At present they show little tectonic activity, though the upheavals have not completely ceased and small spasmodic rises still occur. Due to the above reason Nepal experiences moderate earthquakes frequently. Noted earthquake disasters occurred in Nepal were in 1883, 1934, and in 1988.

Organizational Background:

Survey Department of Nepal under His Majesty's Government, Ministry of Land Reforms and Management was established to conduct the geodetic survey and other mapping activities to make maps, control data, records of land information and other relating geo-information available in an appropriate form for an efficient land management, planning and execution of various development projects.

In order to achieve the above goals the Survey Department has four major wings :

- Geodetic Survey Branch
- Topographical Survey Branch
- Cadastral Survey Branch
- Survey Training Center

GEODETIC SURVEY BRANCH

Geodetic Survey Branch was established as an organization in 1969 under Survey Department of Nepal. After launching the land reform policy of HMG/ Nepal 1963 and also due to the various development projects, the importance and the requirement of establishing geodetic controls in the country for survey and mapping were found essential.

Geodetic survey Branch formed different surveying groups to conduct the field observation in different districts of the country. Branch has completed trigonometrical survey in 43 districts and at present in 5 districts trigonometrical survey is continuing in the country except high Himalayan regions.

The establishment of the First order Geodetic Network was completed by Geodetic Survey Branch in cooperation with Ministry of Defense United Kingdom (MOUK). This task was completed during 1981-84. The first order network consists of 68 well adjusted stations and served as a basis for establishing lower order stations and strengthening the geodetic network in the country. Besides this branch has established 653 second order triangulation points, 3,701 third order triangulation points, 2,04,810 fourth order triangulation points in the country.

Geodetic Survey Branch has 268 skilled and semi skilled manpower working in the organization. Branch also has different sections such as:

- Computing section
- Leveling section
- Gravity section
- GPS section
- Astronomical section
- Data section
- Plotting section

Computing Section

Computing section plays a crucial role in this organization. All the field data are collected and processed in this section. The final out put (Horizontal coordinates) is then provided to different sections of the organization and to other agencies. Mainly the computed coordinates are used for the control of cadastral mapping.

Leveling Section:

The responsibility of this section is to carry out the spirit leveling in various parts of the country. Since 1974-75 till 1998 more than 3238 linear Km of first order high precision leveling, 6081.74 linear Km of second order high precision leveling and 696 Km of third order leveling covering most of the existing roads are completed.

Astronomical Section:

Astronomic observation for position and azimuth are observed by this section. Astronomic observation at seven stations was accomplished by Czechoslovak Geodetic Institute (CGI) in the year 1976-77 in co-operation with geodetic survey Branch. These are called the Laplace stations.

During the observation of first order network 32 new astro stations were observed along with 2 CGI stations. This section still conducts the astronomical observation. The processing of the observational results has not been able to process by the branch itself due to lack of skill in this field. This section has observed the vertical deflection of 40 points.

GPS Section

GPS section is the newly established section in this branch. Apart from its diversified use in the geodetic survey branch it has been used for providing the controls for the cadastral survey. The higher order (Third order) controls are established by the GPS and the lower order (fourth order) control points is established by the conventional method. This is one of the efficient ways of using the both resources, which in one hand over comes the difficulty of higher order observation by using the triangulation method in the mean time the existing manpower and equipment of the conventional surveying are also utilized. GPS has observed 1,637 points in the country.

Gravity Section:

The importance of gravity is less understood by the planners and decision-makers. As a result this is one of the very slow progressing section of the Geodetic Survey Branch. The role of gravity in the field of geodesy helps to define the real shape and size of the earth and it is the vital data source for geoid determination.

This section has observed 990 relative gravity points. Nine absolute gravity points have been established in the country in cooperation with Colorado University.

Data Section:

This section of the Geodetic Survey Branch archives all sorts of data produced by the branch such as coordinates, leveled heights etc. This section is also responsible in selling the data for different government agencies and other development organizations. Formal official letter addressed to the HMG Survey Department is necessary to get a copy of the available data. The data obtained from the Survey Department, Geodetic Survey Branch is not transferable to other agencies.

Plotting Section

This section provides the myler sheets with the control points plotted in the sheet to the Cadastral Survey Branch. This sheet is used to carry on the graphical cadastral survey in the field.

Besides the above facts Geodetic Survey Branch has also been involved in research of Geodetic constrains in the translation, deformation of the Indian plate putting thrust in the upliftment of the Himalayan region on the other hand study implications in future disastrous earthquakes in this region in association with the experts of Colorado University.

TOPOGRAPHICAL SURVEY BRANCH:

Topographical Survey Branch was established in the year of 1970. This branch is responsible in preparing the topographical maps of the whole country. The branch has altogether 710 skilled and semi skilled manpower working to produce and provide topographical maps, land resource maps, and other information to different agencies.

The branch has different sections such as :

- Photogrammetry Section
- Cartography Section
- Printing Section
- Field Section
- Digital Data Base Section

Some of the major completed and on going projects are listed below.

Land Resource Mapping project:

Land resource maps at scale 1:50,000 are available for the entire Nepal. These maps were prepared in cooperation with the Government of Canada (CIDA). These maps were published in 1986. The series of these maps include Land utilization, Land system maps and Land capability maps. Each series has 266 sheets. These maps have been published in mono color only.

Lumbini Mapping Project:

The topographical base map at the scale of 1: 25,000 of the Lumbini Zone of Nepal has already been completed under the assistance of Japan International Co-operation Agency (JICA). There are 41 map sheets in this zone and these maps are available to the users.

Eastern Nepal Topographical Mapping Project:

The topographical base maps covering the Eastern and the Central Development regions of Nepal in 1:25,000 and 1: 50,000 in cooperation with Finnish Government have already been completed. Altogether there are 294 map sheets. This project was launched in 1991 and accomplished in 1996. These maps are also available to the users.

Western Nepal Topographical Mapping Project:

The work continued in the beginning of 1996 to prepare the topographical base maps of Western areas of Nepal again in cooperation with Finnish Government. This project is to produce 1:25,000 scale base maps covering the south western part of the country. There are 262 map sheets in this project area.

In all above three projects separate ground controls, aerial photography, aerial triangulation has completed.

Census Mapping Project:

For national census of the country taking place at the year 2001, Census Mapping Project is preparing up to date maps and orthophotos of the urban areas. The maps and the orthophotos will assists the enumerators to conduct enumeration in a more scientific way. In future all the attribute information collected in the census will be linked with the spatial data prepared by this project.

CADASTRAL SURVEY BRANCH

The main objective of the cadastral survey is to prepare land tax records, cadastral maps and certificate of land ownership. The Cadastral survey branch also differentiates the types of land such as government land, private land and communal land and also the land classification is done in the private land based on the land fertility.

The Cadastral Survey Branch has completed the survey in 75 districts of the country and at present 13 districts are in Re Cadastral Survey. The record shows 1,82,496 hectare of land has been surveyed.

SURVEY TRAINING CENTRE

The Survey Training Center was established in July 1968 with the objective of producing skilled, semi-skilled and medium level technicians to fulfill the need of technical manpower in the department and in other various surveying projects running within the country. The Training Center provides the training to the departmental staffs and the staffs of other departments as well.

Remarks:

Nepal is one of the developing country of the South Asian Region. Nepal has a strong interest in the development of surveying and mapping activities in this region. Some of the development issues taken into consideration are as follows:

- Development of GIS infrastructure within the country and promoting exchange of technical know how between the South Asian regions then extending to Asian and Pacific regions. The cooperation in this field will be more strengthened by the participation in the working group workshop of development of GIS infrastructure of Asia and Pacific regions.
- One of the identified issue is; as Department of Survey has introduced GPS in the mapping activities problem of conversion of World Geodetic System coordinates to the local system has been a matter of prime importance. Due to the lack of skilled technical manpower Department as such has not been able to determine national transformation parameter as a result so many local unauthentic transformation parameters are in use. It gives rise to dis-uniformity in the coordinate conversion.
- The efficient computing software is other matter of retardation in geodetic and other mapping activities.
- The cooperation in the surveying and mapping activities can definitely overcome the these existing obstacles.

PRESENT SITUATION OF NATIONAL GEODETIC NETWORK IN MONGOLIA

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MONGOLIAN STATE ADMINISTRATION
OF GEODESY AND CARTOGRAPHY

At first of all I like to inform you the Geodetic Control Network situation all over the Mongolia.

Position Network is based on Pulkovo 1942 datum Krasovsky reference ellipsoid and established by traditional triangulation and trilateration method. Position Network of Mongolia is shown on the Appendix 1.

Mongolian Leveling Network accuracy is met with second class of Leveling and it's datum based on Baltic sea level. Leveling Network is shown on the Appendix 2 and Gravimetric Network are shown on the Appendix 3.

Aerial Surveying and Mapping Enterprise together with MonMet private company resurveyed National Geodetic Control Network on the 30 points by GPS technology in 1997-1998. There were used 5 GPS receivers, which are called GPS2200 from SOKKIA. The purpose of this re-survey was:

1. To determine the transformation parameters between WGS84 and Krasovsky reference ellipsoid.
2. To determine the height difference between Geoid and Reference ellipsoid.
3. To determine National Reference Ellipsoid.

GPS Network in Mongolia is shown on the Appendix 4.

3 points, which are named 0012, 0033, 0024 are connected to the ITRF system. 5 days continuously observed on the those 3 points and IGS Wuhan, IGS Xian, IGS Irkutsk points of ITRF. These 3 points are used as a base points for the GPS Network in Mongolia.

All GPS points were surveyed by static method in 2 session. Each session was lasted 1.5-2.0 hours with 20 seconds signal interval.

But we didn't achieve to our tasks. It was reasoned of we having little experiences and shallow knowledge of GPS technology.

So we urgently need to train National staffs on GPS technology.

We have an interest to closely cooperate with you on GPS technology, and hope that our co-operation would be expanded in the future.

Thank you for your attention.

