Geometric Rectification Technique For High Resolution Satellite Data Imagery Using New Geocentric-Based Datum

Abdul Wahid Rasib, Mazlan Hashim, Abdullah Hisam Omar and Adhwa Amir Tan
University Technology of Malaysia

Keywords
High Resolution Satellite Image, Geometric Correction, Geocentric Datum

ABSTRACT

Reference system is an important factor in order to verify and identify all measurement and data collection processes. The quality of the outputs is depending on how good a reference system is defined. The existing reference system is based on Rectified Skew Orthomorphic Projection (RSO), which is projected from Malayan Revised Triangulation (MRT) system. Many researches have been carried out to get a global coordinate system that suite with earth's surface. A new datum also called geocentric datum, which is the origin referred to the origin of the earth, gives the best surface reference system for the entire world. In remote sensing applications, datum system (transformation) is important factor to gather spatial data for determination of coordinate location. By using the $RSO_{geodetic}$ datum and $RSO_{geocentric}$ datum as reference surfaces, geometry correction has been performed in terms to see the differences. The results shows that the average RMS errors is 0.2867 meter for north KL and 0.3306 meter for south KL from twelve check points that are measured. Then, the Z-test is carried out and the result shows that the errors of the checkpoints are accepted in 95 percent of confident level. From the comparison analyses between $RSO_{geodetic}$ and $RSO_{geocentric}$ coordinate datum, show that the coordinates changes happen as much as 194.0 meter to 195.0 meter.

INTRODUCTION

The development and onwards movement of the technology today has make the coordinates system been improved from time to time. Most of the coordinates systems in the world early are based on the surface that suite with the topographical surface that called geoids. But now a new datum called geocentric datum that referred to the origin of the earth, given the best surface reference system for the entire world. This is because geocentric datum capable to combine all the coordinate systems into a global coordinate system. Geocentric Datum of Australia (GDA) is one of the earliest that has been developed for local reference system and global reference system (Steed, 2000).

Datum is a surface that been used to descript the absolute and relative of the position of points on earth surface (Indiana Geographic Information Council (IGIC), 2001). This is including the framework in order to define the coordinate system based on the ellipsoid and its parameter such as semi-major (a) and flattening (f). Geocentric datum is suitable for local topography surface because all the measurement aspect for the coordinate point (x, y, z) can be more accurate. In year 2003, Department of Survey and Mapping Malaysia (JUPEM) has produced a new reference datum (geocentric) also called Geocentric Datum of Malaysia (GDM2000). The main objective to form the new datum is to get a more accurate control system and modern

positioning infrastructures with fully support from the Global Positioning System (GPS) activities.

Remote sensing data can fulfill all the application needed in terms of extracting information on earth surface such as land cover, detecting shoreline changes, forest mapping and lots more. Coordinate system is also important in remote sensing image processing (Richards, 1995). This is because all the remote sensing images need to registries in a specific coordinate system for more accurate and precious data measurement and collection.

All the raw remote sensing data, contain geometry effects that been produced by earth curve, atmospheric effects and panoramic effects. The main reason geometry correction been perform is to correct this effects so the image will be rectified in a proper way. Geometry correction is involving the changes of the original data for preprocessing by considering the position pixel and system parameter such as number of ground control points (GCP) and type of interpolation method (Jensen, 1996).

PROBLEM OF STATEMENT

The difference of the reference datum origin between RSO datum and geocentric datum will cause problem in satellite data and topography map data relationship. The accuracy of coordinate will change due to the datum that been used. Control point transformation with different reference will cause problem to the determining coordinate from satellite data and topography map data (Grant, 2000). This will be clearly effect the satellite image especially high-resolution image like IKONOS.

In datum transformation, the parameters changes for the system are complex because of the combination of several parameters in one function. Mathematical model and parameter such as semi major axis (a) and flattening (f) take important role of datum changes for each image correction. Without any model and appropriate parameters, integrating remote sensing image will be difficult.

The relationship between spatial data from satellite image and topography map in order to clarify the accuracy coordinates usually cause problem. Satellite image and topography map is hard to merge without any specific procedures because of the difference image resolution and map scale. "According to Wetch (1992), the topography relief effects still exist after the satellite image has been corrected."

In processing spatial data for high-resolution satellite image, the processing run time will long. This is because of the number of pixel in the image is numerous and its influence the time. Extend from this, the transformation coordinate position will also be impact and there will be problem of clarify the control points.

OBJECTIVE

The main objectives for the study is:

i.   Apply geometry correction technique for high resolution satellite data using new geocentric based datum.
ii.   Perform data spatial accuracy comparison between the geodetic datum and geocentric datum.
iii.   Perform final analysis image comparison based on RMSE value and statistical test for the rectified image on geocentric datum.

SCOPE OF STUDY

The scope of study that need to be fulfil is :

IKONOS satellite data with 1 meter and 4 meter resolution for the Klang Valley area has been used.
GPS Rapid Static method has been apply for ground control point's observation.
For the RMSE ground control points network accuracy analysis, Z test been used in order to evaluate the analysis.

SIGNIFICANT OF STUDY

The important of the study is to evaluate the accuracy of the output data (result) that can be produce from the high-resolution satellite image rectification by using the new RSO geocentric datum compared to the existing RSO geodetic datum. This is important to evaluate which of the both datum giving the more accurate image rectification and the position of the points in the image. The result will conclude whether the new datum is capable of producing more accurate coordinate position through out the country.

Coordinate transformation can easily perform to the satellite image and topography map if JUPEM would like to use GDM2000 as reference datum. With this study, the effects of geocentric datum to the satellite image can be detected. The changes will show how much the different relief that happen to the satellite image compared to the topography map. This is important to view whether the satellite image is displacement exactly as same as the topography map. Beside that, with this study the procedure how to implement the geocentric datum to the satellite image can be identify. Actually, this will help in terms of knowing the geocentric datum implementation process. Each of processing steps can be carried out for the future needed.

The result of the study can become as the prototype rectified image for other satellite images. This will help to verify the GCP in order to improve the satellite image and the correlation in model order to gain the accuracy and precious of the data. With this, datum transformation is implement easily for determining the effectiveness of the new geocentric based datum in satellite image geometry correction.

STUDY AREA

Klang Valley has been choosing as the study area because of the compact area network that has been used as the main reference in the country. The relationships between the reference datum with the area lots network can be study for the changes coordinates. Information regarding the boundary of the area needs to be identified for the national mapping. A total study in term of determines the changes that will happen if the geocentric datum been implemented need to been done. Figure 1, Figure 1a and Figure 1b shows the study area.
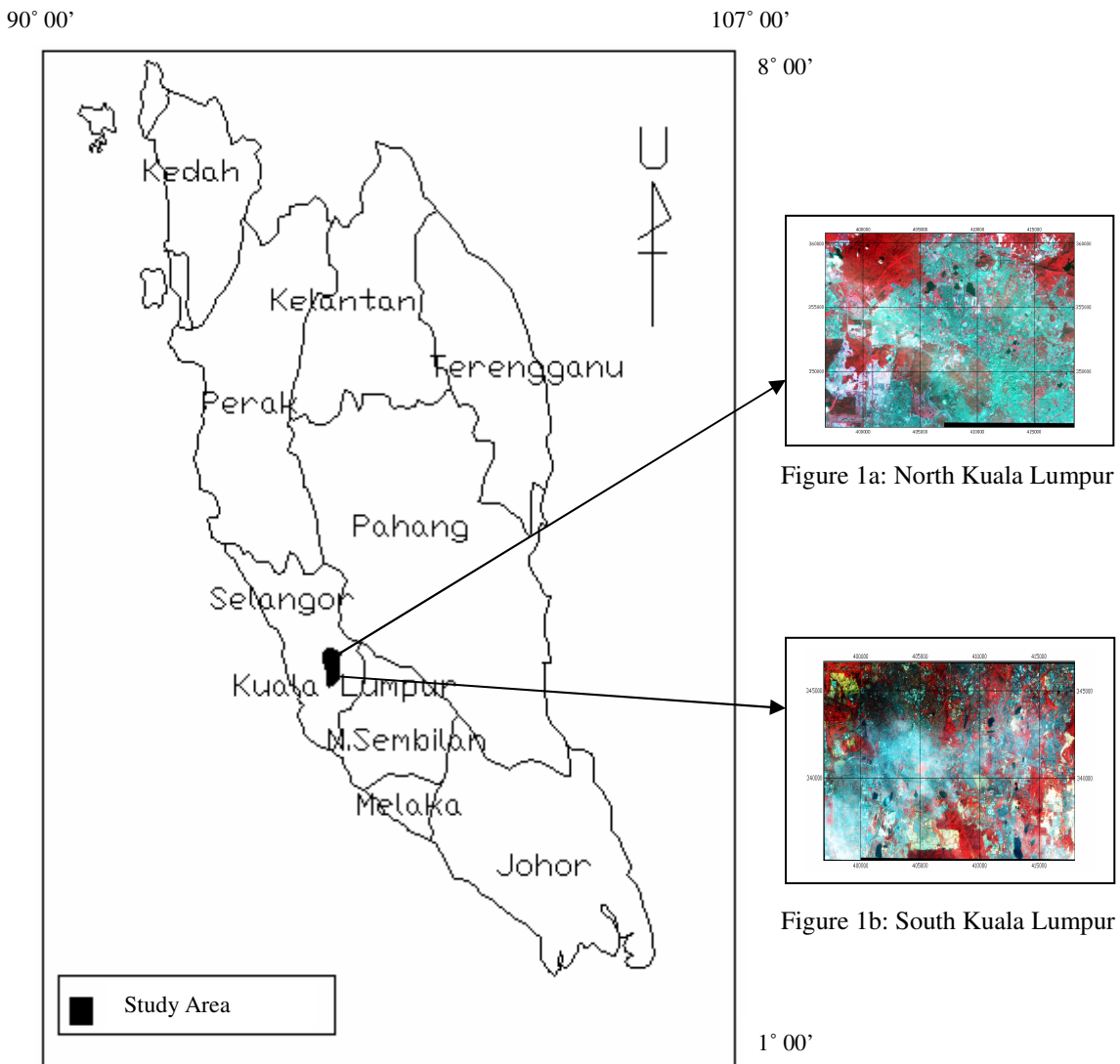
90° 00'   107° 00'

8° 00'

Figure 1a: North Kuala Lumpur

Figure 1b: South Kuala Lumpur

1° 00'

Figure 1: Study Area (Kuala Lumpur)

METHOD

At the beginning the high-resolution satellite image will be subset into the interest of study area only. This area is containing all the distribution of the control point that been collected by the GPS observation. The coordinate then been converted from WGS84 coordinate system into the geocentric coordinate system by transformation coordinate program. Then, the entire coordinate will be applied to the satellite image for image geometry correction processing. The Bi-linear interpolation with second-degree polynomial resampling method has been used. This is because Bi-linear interpolation can predict big control point network as same as real world (Richards, 1995). From the result, accuracy analysis will be evaluating the RMSE value and Z-test in order to clarify the accuracy of the image geometry correction. Figure 2 shows the there flowchart for this study. Table 1 shows the parameter that been used for geometry correction process.
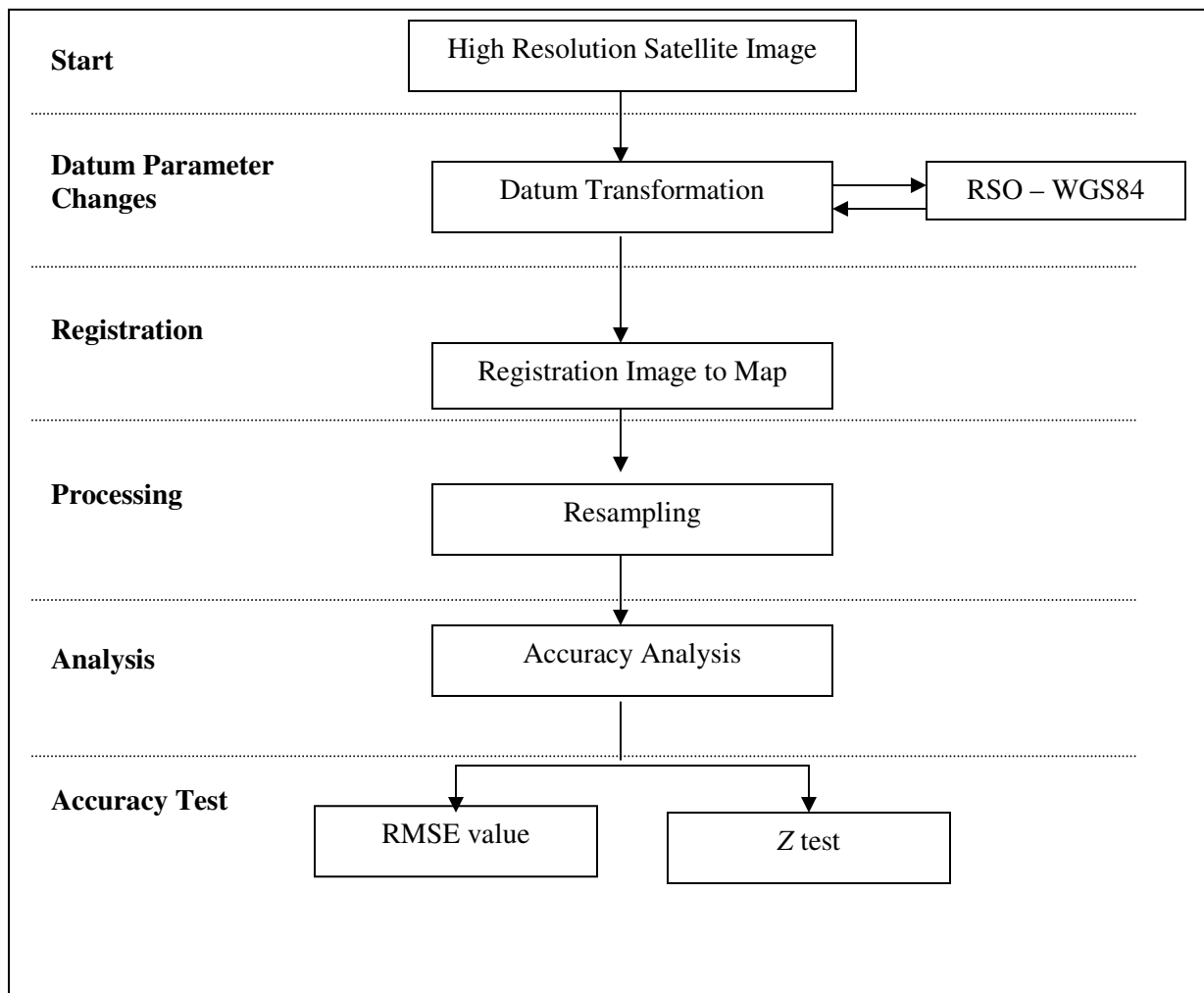

Figure 2: Flowchart of study

Table 1: Geometry Correction Parameter

Parameter	Type/No.

Projection	RSO Geodetic	RSO Geocentric
Spheroid	Modified Everest	GRS80
Datum	Kertau 1948	GRS80
False Easting	804,671	-
False Northing	-	-
No of Control Point	28	28
No. of Check Point	25	25
Resampling Technique	Bi-Linear Interpolation	Bi-Linear Interpolation
Geometry Model	Second Degree Polynomial	Second Degree Polynomial

RECTIFICATION RESULT

The rectification accuracy of scene for north KL is 0.30 pixels (x direction) and 0.28 pixels (y direction) and scene for south KL is 0.39 pixels (x direction) and 0.30 pixels (y direction) using all 53 GCPs based on new geocentric datum. Table 2 and 3 show the results of RMSE of GCPs and checkpoints. The accuracy is almost constant for the geocentric datum compared to geodetic datum. The RMSE value for geocentric datum is smaller than the RMSE value for geodetic datum. There is several factors that contribute for the result which is the different type of datum that been used, the data input quality for control points and placing the control points in the image.

Table 2: RMSE of rectification for north KL

Datum	No. Of CPs	Ground Contol Points		Check points	
		RMSE		RMSE	
		X	Y	X	Y
Geocentric	28	0.3038	0.2782	0.1944	0.2107
Geodetic	28	0.3678	0.2738	0.3731	0.3657

Table 3 : RMSE of rectification for south KL

Datum	No. Of CPs	Ground Contol Points		Check points	
		RMSE		RMSE	
		X	Y	X	Y
Geocentric	28	0.3867	0.2020	0.1284	0.3046
Geodetic	28	0.4482	0.6133	0.2588	0.3971

ACCURACY ANALYSIS

Statistical Analysis

From the RMSE value results for geocentric datum, statistical analyses using the Z-test need to be carrying out in terms of evaluating the quality of the RMSE value. This is to ensure whether the RSME total value can be accepted or not for the observation points that been tested. Hypothesis Null has set up the RSME value for north KL is 0.2867 meter and for south KL is 0.3306 meter can be accepted if the Z value is lower than 1.96 in 95 percent of confident level. Based on the Z-test, the RMSE values for the both scene is accepted. This shows that the RMSE value for the image accuracy is valid. Table 4 shows the RMSE values for both scene and the result the Z-test value.

Table 4: RMSE and Z-Test Value

Area	RMSE	Z-Test
North KL	0.2867	0.6399
South KL	0.3306	0.5423

RSO Geodetic and RSO Geocentric Coordinate Comparison Analysis

From the final result, there is a different between this two datum. The results shows that rectified image using RSO geocentric datum has been displacement as much as –5.703 meter (northing) and 194.927 meter (easting) for north KL meanwhile for south KL is –5.694 meter (northing) and 194.873 meter (easting) averagely. Table 5 shows the different of the both datum.

Table 5: Coordinate Changes in North KL and South KL

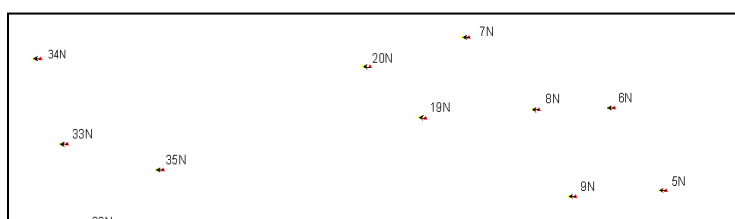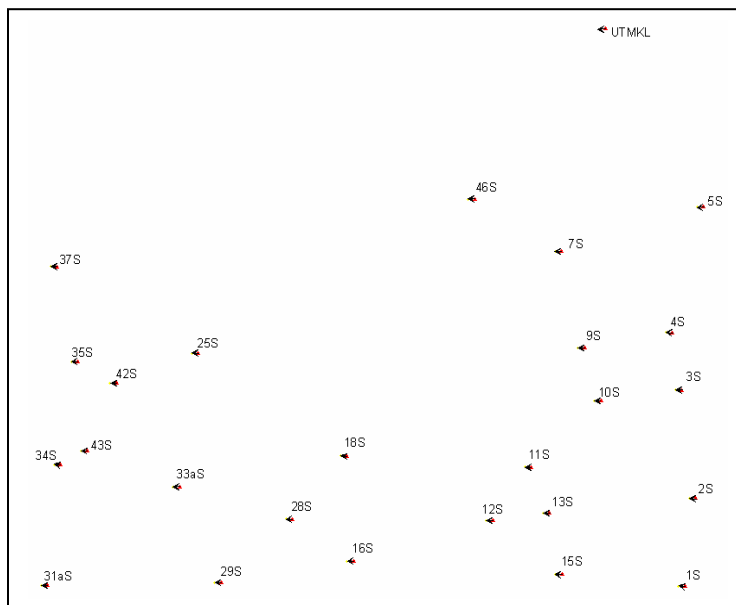|	North KL (Geocentric Datum)		South KL (Geocentric Datum)	
	Δ E (m)	Δ N (m)	Δ E (m)	Δ N (m)
Min	-5.7030	194.927	-5.6943	194.873
Maximum	-5.6593	194.962	-5.6472	194.898
Minimum	-5.7402	194.899	-5.7373	194.849
Total	-159.682	5457.960	-142.357	4871.830

Figure 3: North KL Coordinates Changes

Figure 4: South KL Coordinated Changes

The coordinates change has been show in vector direction in Figure 3 and Figure 4. Totally, the coordinates change is uniform into one direction, which is the earth origin. Based on this, the geocentric datum will synchronize the coordinate into a specific origin so then the coordinates system can be use globally. Figure 5 shows the changes for the road line between both datum.
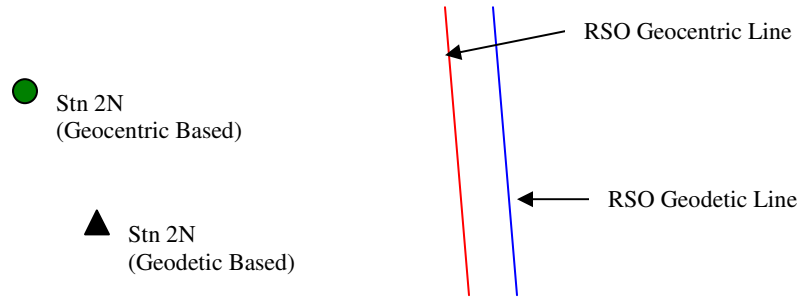
Figure 5: Vector Line Changes Between RSO Geodetic and RSO Geocentric
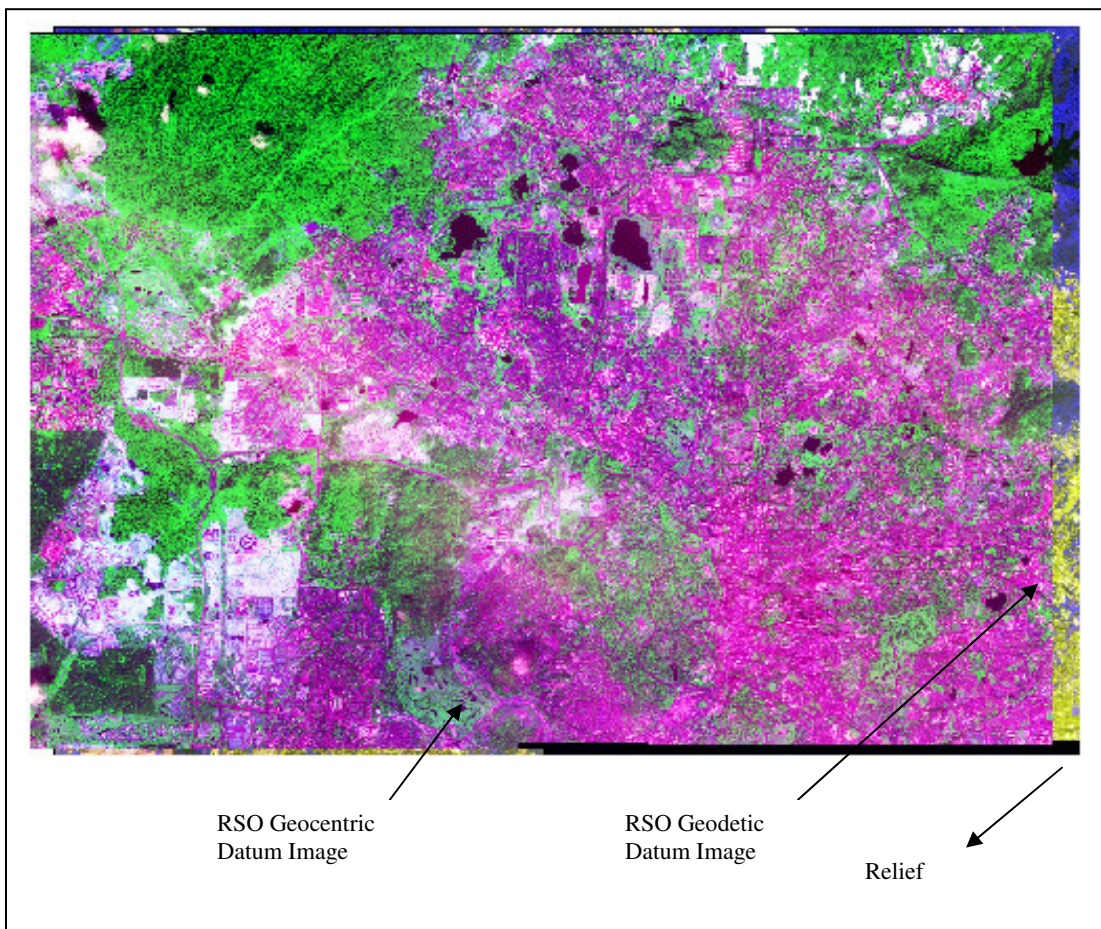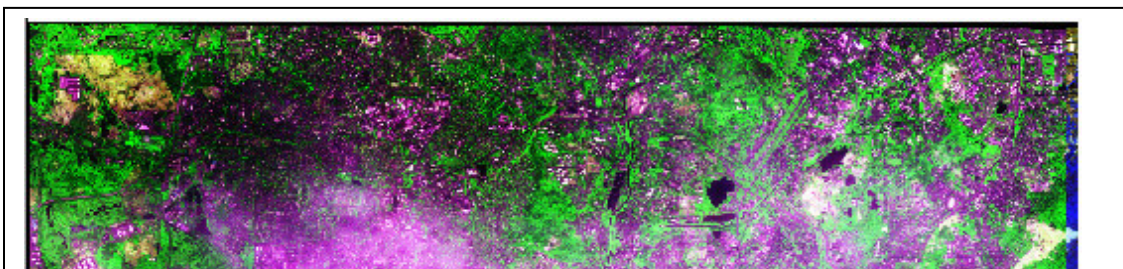

Figure 6: North KL Satellite Image Changes

RSO Geocentric
Datum Image
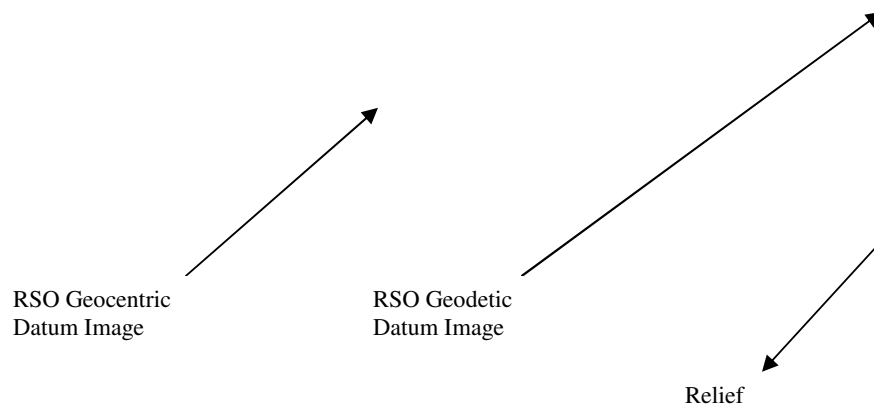
RSO Geodetic
Datum Image

Relief

Figure 7: South KL Satellite Image Changes

From the satellite image that has been overlaid between RSO geodetic datum and RSO geocentric datum shows that there is different between this both datum. Figure 6 and Figure 7 shows the result for the overlaid image that has been rectified for north KL and south KL. The displacement image is almost about 200.0 meter. The result is similar to the topography map that has been changed the projection into RSO geocentric (JUPEM, 2003). Clearly seen that the changes of the ear reference system will affected the coordinate system for the satellite image.

CONCLUSION

Briefly, the using of geocentric datum on high-resolution satellite image will effects the system of coordinates transformation. The changing reference system from Modified Everest

(Kertau 1948) to GRS80 will allows coordinates transformation take place easily. In future, a universal coordinate system can be produce for integrating the local coordinate system with international. The results for the geometry correction for north KL are 0.4120 pixels and for south KL is 0.4120 pixels based on geocentric datum. The coordinates changes from RSO geodetic to RSO geocentric are almost about 200.0 meter for each coordinate.

As a conclusion, the result from the analysis shows that it is possible to used the new reference system (RSO geocentric) due to replace the old datum (RSO geodetic). The effectiveness using the RSO geocentric datum on IKONOS satellite image is easy to combine with topography map if JUPEM going to implement the RSO geocentric datum as new national reference surface.

RECOMMENDATION

Further study can be done for geocentric datum by studying the 3D surface (height value). The 3D surface of geocentric datum can displayed the earth surface compared to geodetic datum and the changes of the datum can be evaluated. In fact, analysis between topography map and remote sensing image can also been done in terms of evaluating the changes. The clarify accuracy can be produced for satellite image compared to topography map which is both are based on geocentric datum. For advance study, geocentric datum can be applied to variety level of resolution images to see the differences and the effects of the multi resolution images. This because each image has it own resolution and accuracy analysis result due to the changes of the reference datum.

REFERENCE

Abdullah Hisham Omar (2003), " The Development of Georeferencing Technique for Conversion of Existing Topographic Data t oNewGeocentric Based Datum". FKSG-UTM, Malaysia.

Abd. Majid, Shahrum Ses, Ghazali Desa (2003), "Technique for The Integration of Digital Coordinated Cadastral Data With Mapping Data". FKSG-UTM, Malaysia.

Annie Hui, Soo Chin Liew, Leong Keong Kwoh, dan Hock Lim (2000), "Extraction and Utilization of Geometrical and Contextual Information in very High Resolution IKONOS Satellite Imagery". Journal Gisdevelopment 2001

Autralian Surveying & Land Information Group (1994). " Geocentric Datum of Australia : A New Era of Australis." Belconnen: Australian Surveying & Land Information Group.

Chao-hsiung Wu (2000), "The Rectification of High Resolution Remote Sensing Satellite Imagery". Journal Gisdevelopment 2001

Chong, S.L. (1999), " Penggunaan GPS Dalam Sistem Kadaster di Malaysia." Tesis Master, FKSG-UTM, Malaysia.

Featherstone, W. (1994). " An Update Explaination of The Geocentric Datum of Australia (GDA) and It Effects Upon Future Mapping." *Cartography.*

Gao, J. (2002). " Integration of GPS with Remote Sensing and GIS : Reality and Prospect."
    Photogrammetri Engineering & Remote Sensing. Vol. 68 No.5.

Jabatan Ukur dan Pemetaan Malaysia (JUPEM) (2000), "A Technical Manual on the
    Geocentric Datum of Malaysia (GDM2000)". Department of Survey and Mapping Malaysia.

Jensen, J.R. (Ed.) (1996), "Introductory Digital Image Processing, A Remote Sensing
    Perspective," Prentice Hall Series In Geographic Information Science, Second Edition.

John Allan W (2001), "High resolution geographic imagery and its impact on GIS". Journal
    Gisdevelopment 2002

John A.Richards (1995), "Remote Sensing Digital Image Analysis, An Introduction", Second,
    Revised and Enlarged Edition.

Kamaruddin Mohd Omar and Abd Majid A.Kadir (1999), "Monograf - Pelarasan Ukuran I dan
    Pelarasan Ukuran II (Teori dan Praktis)" Pensyarah FKSG-UTM, Malaysia.

Majid Kadir, Wan Abd. Aziz Wan Mohd. Akid dan Kamludding Omar (1998). " GPS Positioning
    By Rapid Static Technique." *The Surveyor*. **33** (3). 41-53.

Majid Kadir et. Al. (1998). "Introducing Geocentric Datum In Defining Coordinate System of
    Peninsular Malaysia : Studies on Coordinat Tranformations." *The Surveyor*. **33** (4). 40-67.

Mohd Ibrahim Seeni Mohd and Shahruddin Ahmad (2000), "Orthorectification of Stereo Spot
    Panchromatic and Radarsat Fine Mode Data using Orbital Parameters and Digital Elevation
    Model". Journal Gisdevelopment 2001

Noraidah Keling (2002), " Aplikasi ArcView (N Order Transform) Dalam Transformasi Sistem
    Rujukan Geografi Bagi Data Topografi". Tesis Sarjana Muda, FKSG-UTM, Malaysia.

Robert A. Schowengerdt (1997), "Remote Sensing, Model and Methodsfor Image Processing",
    Department of Electrical and Computer Engineering, University of Arizona.

Shahrum Ses dan Abd. Majid A. Kadir (1997), " Geodesi Asas – Nota Kuliah." Pensyarah FKSG-
    UTM, Malaysia.

Shiro Ochi dan Masataka Takagi (1996), "Ground Truth Database with Portable GPS for
    Education". Journal Gisdevelopment 1997

Singh S K (2001), "Coordinate Transformation between Everest and Wgs – 84 Datums". Journal
    Gisdevelopment 2002

Sompong Wisetphanichkij, Kobchai Dejhan, Fusak Cheevasuvit, Somsak Mitatha dan Somkid
    Hanpipatpongsa (1998), "An Improvement of Geometric Correlation of Satellite Image".
    Journal Gisdevelopment 1999

Srivastava, V.K. (2001). "Significance of Global Positioning System (GPS) Measurement in
    Georeferencing of Remote Sensing Images an input in GIS." The Asian GPS Conference, 20-
    30 October 2001. New Delhi: 51-52.

Tee, Chong Seng (1997). " Unjuran RSO dan Cassini Soldner Menggunakan Datum Geosentrik." Tesis Sarjana Muda, FKSG-UTM, Malaysia.

V.Vorrawat, F.Cheevasuvit, K.Dejihan, S.Mitatha dan A.Somboonkaew (1997), "Geometric correction by GPS". Journal Gisdevelopment 1998

Wong Kok Siong (1999), " Ke Arah Perlaksanaan Sistem Koordinat Kadaster Homogen Untuk Semenanjung Malaysia." Tesis Master, FKSG-UTM, Malaysia.

Wan Aziz., Majid. K, dan Sahrum, S. (2000), "Cadastral reform in Malaysia: A vision to the 2000s" Journal Gisdevelopment 2001