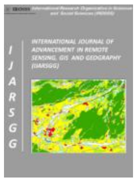
ISSN 2321–8355
Research Article

IJARSGG (2013) Vol.1, No.1, 49-60

IROSSS
Advancing Sciences and Social Sciences for Mankind

International Journal of Advancement in Remote Sensing, GIS and Geography



BLOCK ADJUSTMENT TECHNIQUE, PROCESSING & GEOMETRIC QUALITY ASSESSMENT OF CARTOSAT-1 FOR UTTARAKHAND HIMALAYAN TERRAIN

Peeyush Gupta*[I], M.M.Kimothi[II], P.Saklani[III]

[I, II, III] Uttarakhand Space Application Centre, Dehradun, Uttarakhand, India. (*peeyushgis@gmail.com)*

ABSTRACT: High resolution data have high relief displacement in hilly terrains. Stereo imaging from space borne platforms offers information about terrain elevation besides supplying spectral reflectance of the scene. This greatly assists the analysis and interpretation of images in terms of identifying slopes, surface material, waterways, vegetation growth, etc. Applications like urban planning, agriculture, defense etc., need to use Digital Elevation Model (DEM) derived from stereo images, which is an important component of geo-spatial data. Therefore, Cartosat-1 stereo pair based Digital Elevation Model (DEM) has been generated using the Rational Polynomial Coefficients (RPC) supplied along with the data products of Uttarakhand state. Block triangulation have been performed using stereo data (Band A & Band F) products with RPC and some of the latest Carto Dem Chips (Tile quality Validation), (Source: NRSC). This study presents the procedure followed for Block adjustment technique, processing and geometric quality assessment of Cartosat-1 for Himalayan terrain with the help of advance photogrammetry approach.

Keywords: DEM, RPC, Cartosat, Stereo Pair, Himalaya

---

1. INTRODUCTION: One of the primary goals of CARTOSAT-1 mission was to generate, archive and disseminate seamless DEM, and Ortho-images in usable units (typically, Tiles with 7.5'x7.5'~13.5 km x 13.5 extents) from a central data processing facility to facilitate the Indian remote sensing users and cartographers (1).

Prior to performing any photogrammetric tasks within LPS Project Manager, a block must be created. Block is a term used to describe and characterize all of the information associated with a photogrammetric mapping project, including: Projection, spheroid and datum information, Imagery used within a project, Camera or sensor model information associated with the imagery, GCPs and their measured image positions and geometric relationships between the imagery in a project and the ground. The GCPs are used to determine camera/sensor orientation, and the DEM is used to represent topographic relief. Both factors being considered, the geometric distortions associated with an image can be removed. A block containing a strip of imagery comprises two or more images adjacent to one another containing common overlap areas. Typically, adjacent images contain approximately 60% overlap (2).

GCPs are the features on ground whose precise ground coordinates are known and which are identifiable on the image. A database having well distributed network of ground control points over Indian landmass with ground coordinates obtained using differential GPS and image chips for manual/auto correlation purpose is used for operational use.

Block triangulation is the process of establishing a mathematical relationship between the images contained in a project, the camera or sensor model, and the ground. The information resulting from triangulation is required as input for the ortho rectification, DEM generation, and stereo pair creation processes. The term block triangulation, or simply triangulation, is used when processing satellite imagery. The techniques differ slightly as a function of the type of imagery being processed (3).

LPS Project Manager uses a mathematical technique known as block adjustment for block triangulation (4). General points are showing in fig.I. Block adjustment provides three primary functions:

1. Block adjustment determines the position and orientation for each image in a project as they existed at the time of photographic or image exposure. The resulting parameters are referred to as exterior orientation parameters. In order to estimate the exterior orientation parameters, a minimum of three GCPs is required for the entire block, regardless of how many images are contained within the project.

2. Block adjustment determines the ground coordinates of any tie points manually or automatically measured on the overlap areas of multiple images.

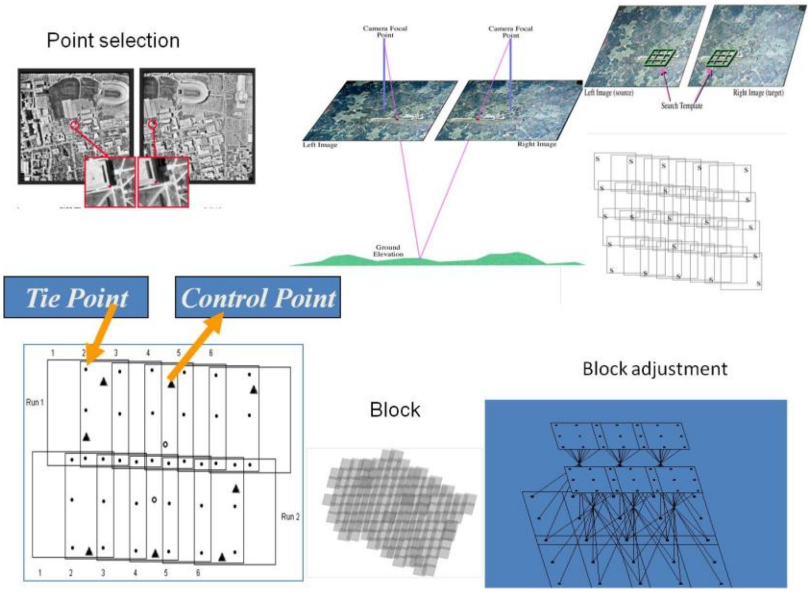


Fig I: Showing Point selection, common point, tie point, control point, block and block adjustment

3. Block adjustment minimizes and distributes the errors associated with the imagery, image measurements, GCPs, and so forth. The block adjustment processes information from an entire block of imagery in one simultaneous solution using statistical techniques (i.e. adjustment component) to automatically identify, distribute, and remove error. Because the images are processed in one step, the misalignment issues associated with creating mosaics are resolved (5).

Interior orientation defines the internal geometry of a camera or sensor as it existed at the time of image capture. The variables associated with image space are defined during the process of defining interior orientation. Interior orientation is primarily used to transform the image pixel coordinate system or other image Coordinate measurement system to the image space coordinate system.

Exterior orientation defines the position and angular orientation of the camera that captured an image. The variables defining the position and orientation of an image are referred to as the elements of exterior orientation. The elements of exterior orientation define the characteristics associated with an image at the time of exposure or capture (6).

The instrumental component of establishing an accurate relationship between the images in a project, the camera/sensor, and the ground is GCPs. GCPs are identifiable features located on the Earth's surface whose ground coordinates in X, Y, and Z are known. A full GCP has associated with it X, Y, and Z (elevation of the point) coordinates. A horizontal GCP only specifies the X, Y coordinates, while a vertical GCP only specifies the Z coordinate.

The features on the Earth's surface are commonly used as GCPs such as Intersection of roads, utility infrastructure, intersection of agricultural plots of land, Survey benchmarks etc (7).

When processing one image for the purpose of orthorectification (that is, a single frame ortho rectification), the minimum number of GCPs required is three. Each GCP must have an X, Y, and Z coordinate associated with it. The GCPs should be evenly distributed to ensure that the camera/sensor is accurately modeled.

When processing a strip of adjacent images, two GCPs for every third image are recommended. To increase the quality of ortho rectification, measuring three GCPs at the corner edges of a strip is advantageous. Thus, during block triangulation a stronger geometry can be enforced in areas where there is less redundancy such as the corner edges of a strip or a block (8).

A tie point is a point whose ground coordinates is not known, but is visually recognizable in the overlap area between two or more images. The corresponding image positions of tie points appearing on the overlap areas of multiple images is identified and measured. Ground coordinates for tie points are computed during block triangulation. Tie points can be measured both manually and automatically. Tie points should be visually defined in all images. Ideally, they should show good contrast in two directions, like the corner of a building or a road intersection. Tie points should also be distributed over the area of the block (9).

Selecting and measuring tie points is very time-consuming. In recent years, one of the major focal points of research and development in photogrammetry has been automated triangulation with automatic tie point collection as the main issue.

In this study latest Carto Dem Chips (Tile quality Validation) used to generate DEM from Cartosat-1 stereo pairs. It is to be noted here that system corrected Rational Polynomial Coefficients (RPC) were used. Block triangulation have been performed using two stereo ortho kit products with RPC.

2. STUDY AREA: The Study area is Uttarakhand State (Lattitude-28°43' N to 31°27' N & Longitude-77°34' E to 81°02' E). It has a geographic area of 53,566 km², of which 93% is mountainous and 64% is covered by forest. Most of the northern parts of the state are part of Greater Himalaya ranges, covered by the high Himalayan peaks and glaciers. Middle part is covered by dense forest and southern part is covered by plain areas.

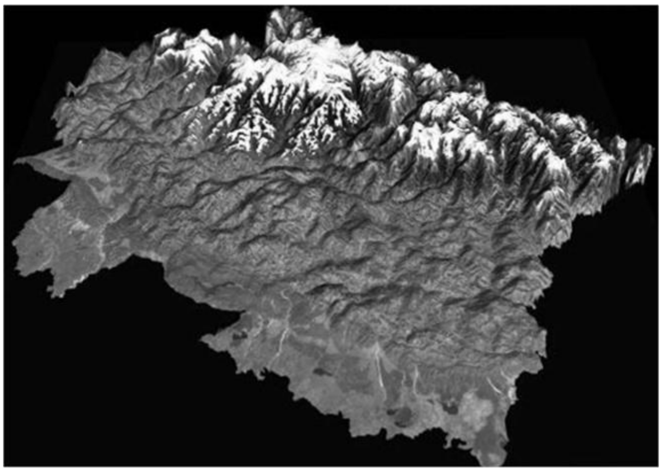


Fig II: Study area of Uttarakhand Himalayan Terrain

3. DATA USED: For Digital Elevation Model from Cartosat-1 satellite data following data sets were used. Total number of Cartosat-1 data is 163 stereo pairs showing in fig III. The production approach identified for generating Carto-DEM is through autonomous processing based on the use of limited Ground Control Points (GCPs) using Crto Dem Chip (Tile Quality Validation) for reference data showing in fig IV.

Carto-DEM chip contents digital images of raster DEM and orthorectified satellite imagery. Data type DEM is signed short (2 bytes) and ortho image is unsigned short (2 bytes). Ortho image resolution is 1/12 arc sec~2.5 m and DEM posting is 1/3 arc sec ~10 m. DEM accuracy (Planimetric) is 15 m. DEM accuracy (Elevation) is 8 m.

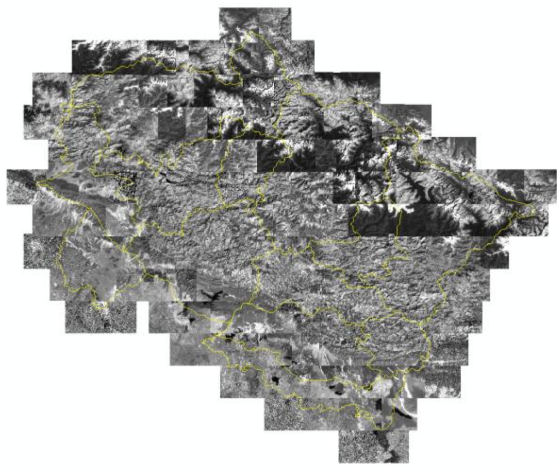


Fig III: Cartosat-1 raw data

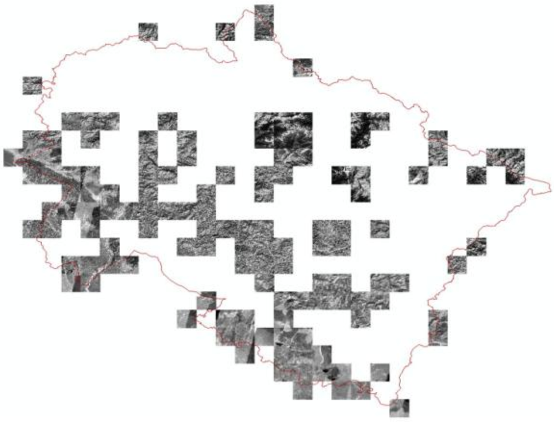


Fig IV: Carto-DEM Chips reference data

4. METHODOLOGY: In this study, leica photogrammetry suite (LPS) 11.0 has been used to perform the block triangulation and block adjustment. The following standard specifications have been applied for this methodology.

A. SPECIFICATIONS OF BLOCK:

Property	**Specification**
Block property-GCP Standard Deviation X	9m to 10m
Block property - GCP Standard Deviation Y	9m to 10m
Block property - GCP Standard Deviation Z	9m to 10m
Reference Coordinate System - Horizontal	Project:Geographic (Lat/Long) Datum:WGS 84
Reference Coordinate System - Vertical	Vertical Spheroid: WGS84 Vertical Datum :WGS84

B. SPECIFICATIONS OF GCP:

Property	Specification
GCP marking	Point having high contrast with respect to the surroundings
Number of GCPs between the Band A and Band F	The order of 5 to 9 that too of well distributed.
GCPs between overlap regions at side and in the same path	Minimum two 4 ray GCPs. This 4 ray GCP has to be extended to 6 ray GCP is three stereo pairs overlap occurs

C. SPECIFICATIONS OF TIE POINTS:

Property	Specification
Tie points between Band A and Band F	Should be well distributed. A minimum of 50 tie points are sufficient if the area is flat. If the area is rugged topography then it is advised to increase the number of tie points. Automatic tie points can also be used but recommended to visually check for correct placement.
GCPs between overlap regions at side and in the same path	Minimum five 4 ray tie points. This 4 ray tie points has to be extended to 6 ray GCP is three stereo pairs overlap occurs For multi ray tie point it is suggest to identify manually.

C: SPECIFICATIONS FOR TRIANGULATION:

Property	Specification
Maximum normal iterations	10
Ground convergence value (m)	0.00010
Image point SD (pixels)	X : 0.33 and Y 0.33
Polynomial order	1
Refinement summary (Total)	Less than 0.9
Residual limits at X, Y and Z	X : less than 1.9, Y less than 1.9 and for Z :less than 2.5

This software supports reading of the data, manual or automatic GCP/tie point (TP) collection, geometric modeling of Cartosat-1 using the RPC method. Fig V is showing flow diagram of DEM generation methodology.

Total No. of ground control points are 331 based on tile quality validation of carto dem chips.Multi tie points are 530.Auto tie points are 103823.check points are 44.Horizontal points are 3.All points are distributed over the block.Table I is showing the points statics of GCP, multi tie, horizontal, check, auto tie points. Fig VI to XVI showing the distribution of GCP, multi tie, horizontal, check, auto tie points.

Table I: Points statics of GCP, multi tie, horizontal, check, auto tie points

Points	Points Ids	Ray	Number
GCP	400001-400331	2 Ray-125 4 Ray-147 6 Ray-51 8 Ray-08	331
Multi Tie	700001-700530	4 Ray-462 6 Ray-61 8 Ray-07	530
Horizontal	500001-500003	2 Ray-02 4 Ray-01	3
Check	600001-600044	2 Ray-18 4 Ray-18 6 Ray-07 8 Ray-01	44
Auto Tie	000001-103823	2Ray-103823	103823

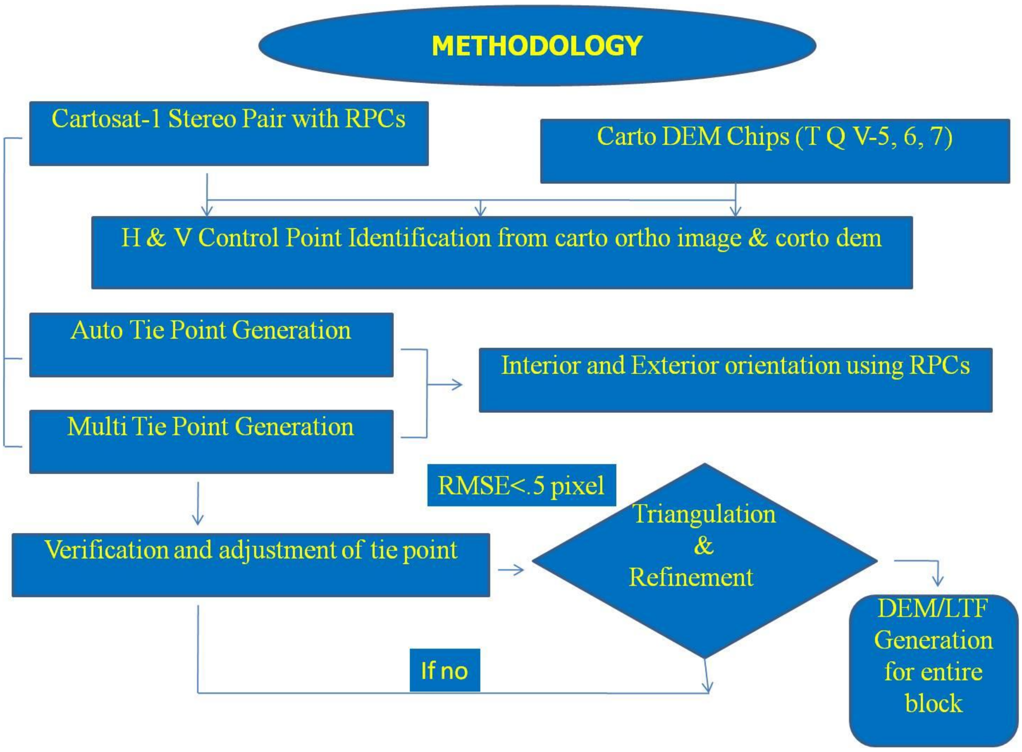


Fig V: Methodology of DEM generation

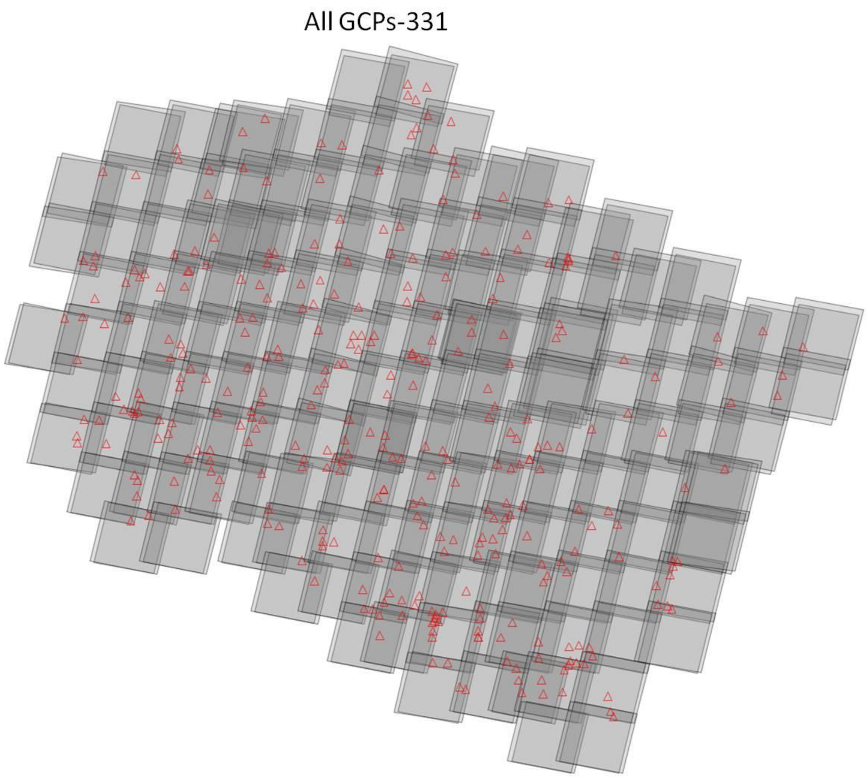


Fig VI: Distribution of all Ground control points

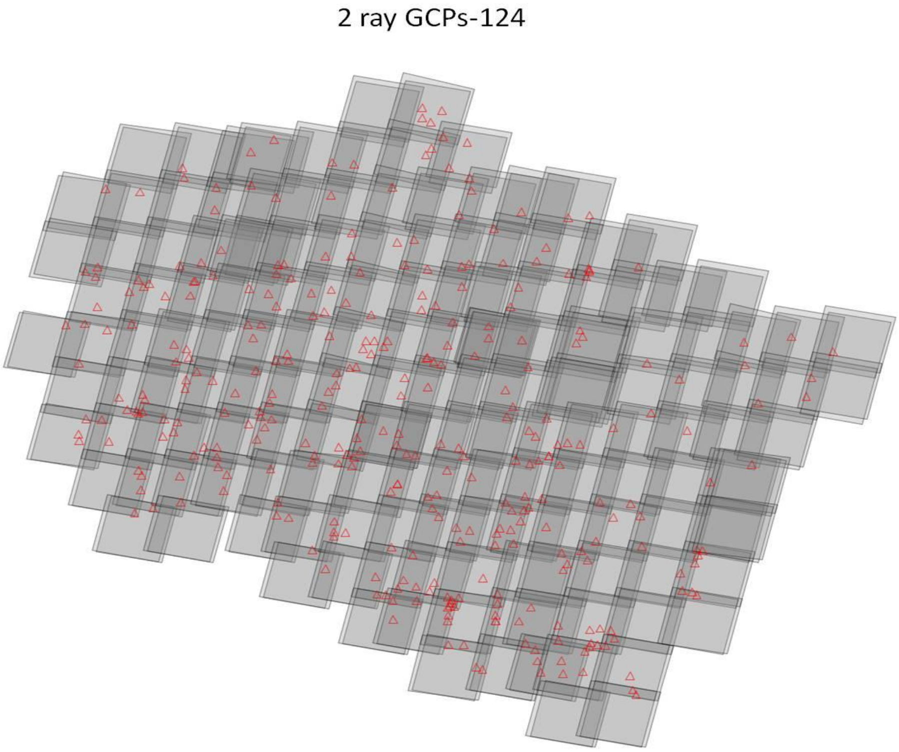


Fig VII: Distribution of 2 ray Ground control points

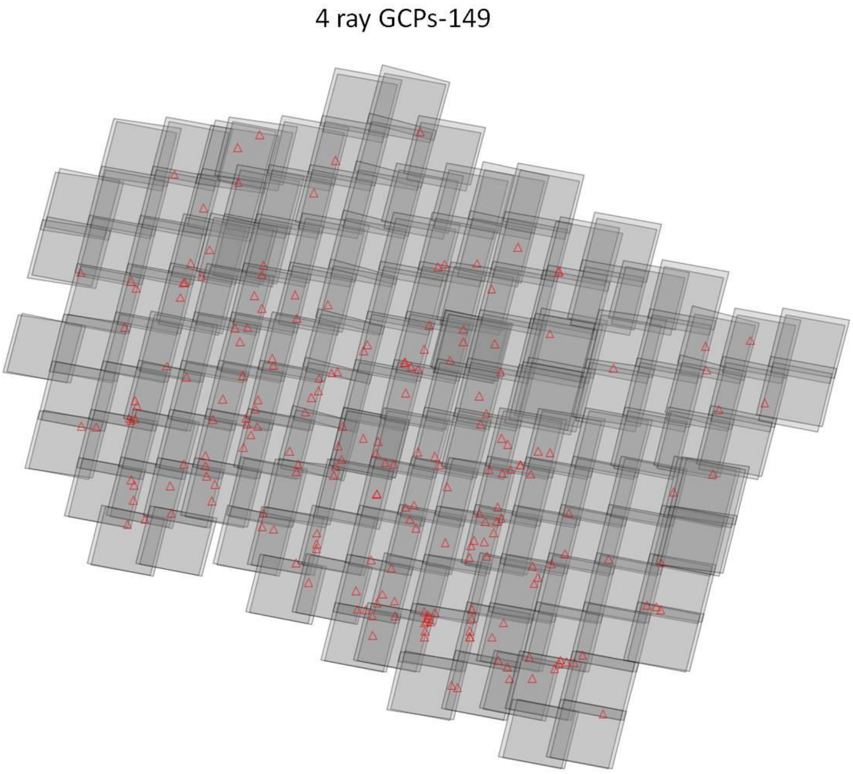


Fig VIII: Distribution of 4 ray Ground control points

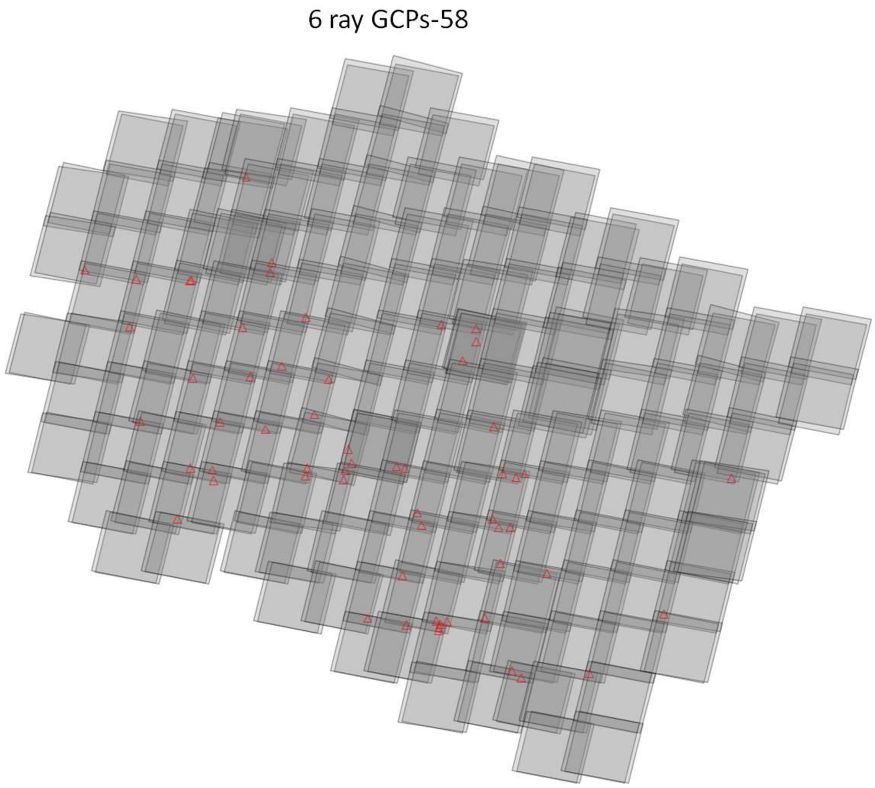


Fig IX: Distribution of 6 ray Ground control points

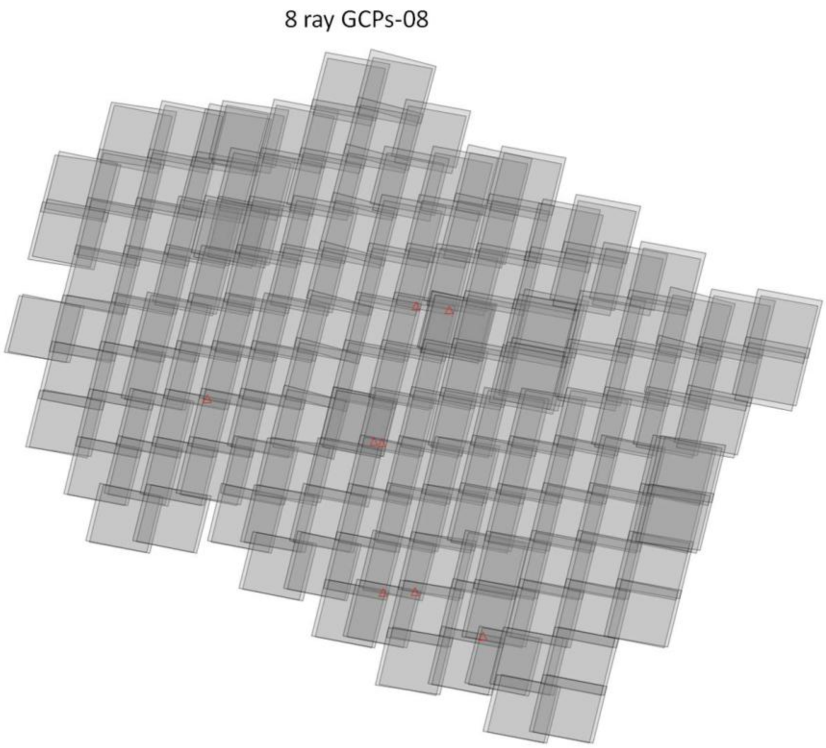


Fig X: Distribution of 8 ray Ground control points

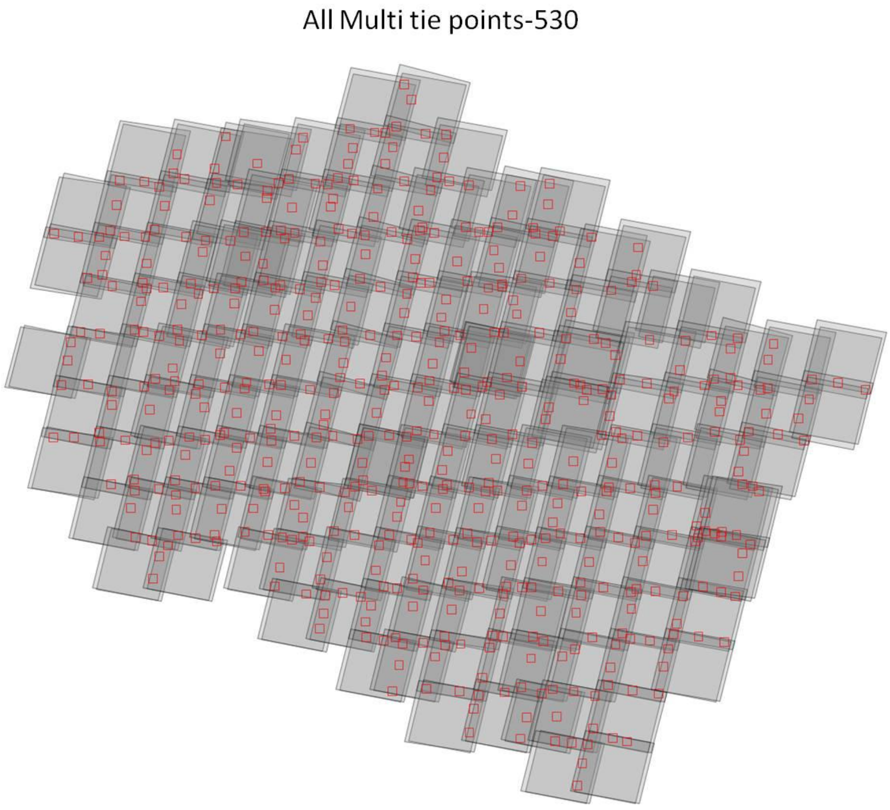


Fig XI: Distribution of all multi tie points

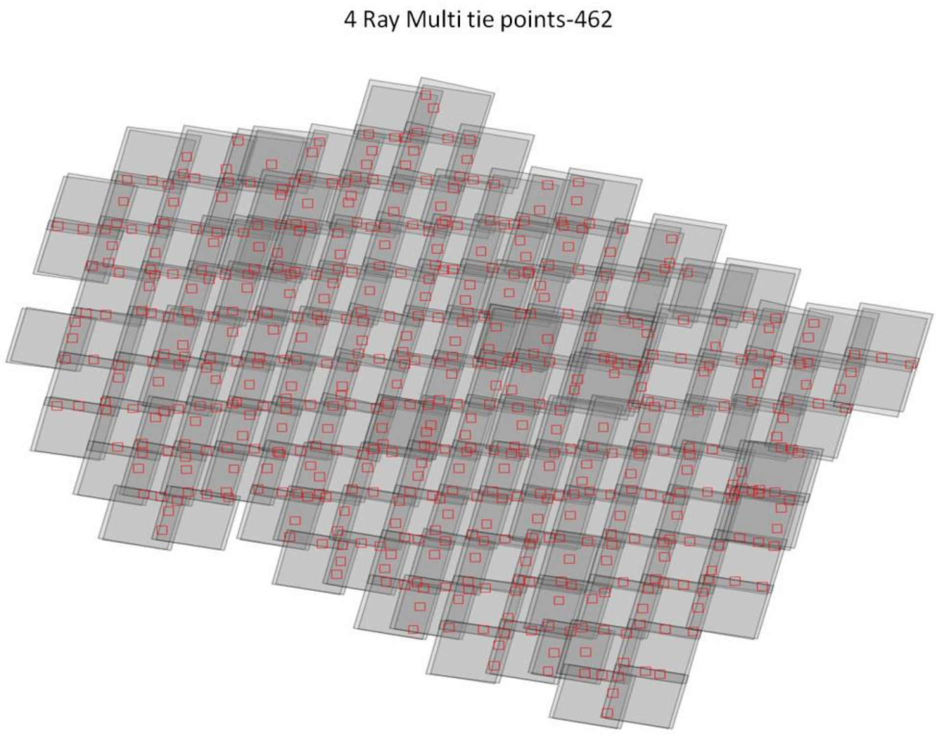


Fig XII: Distribution of 4 ray multi tie points

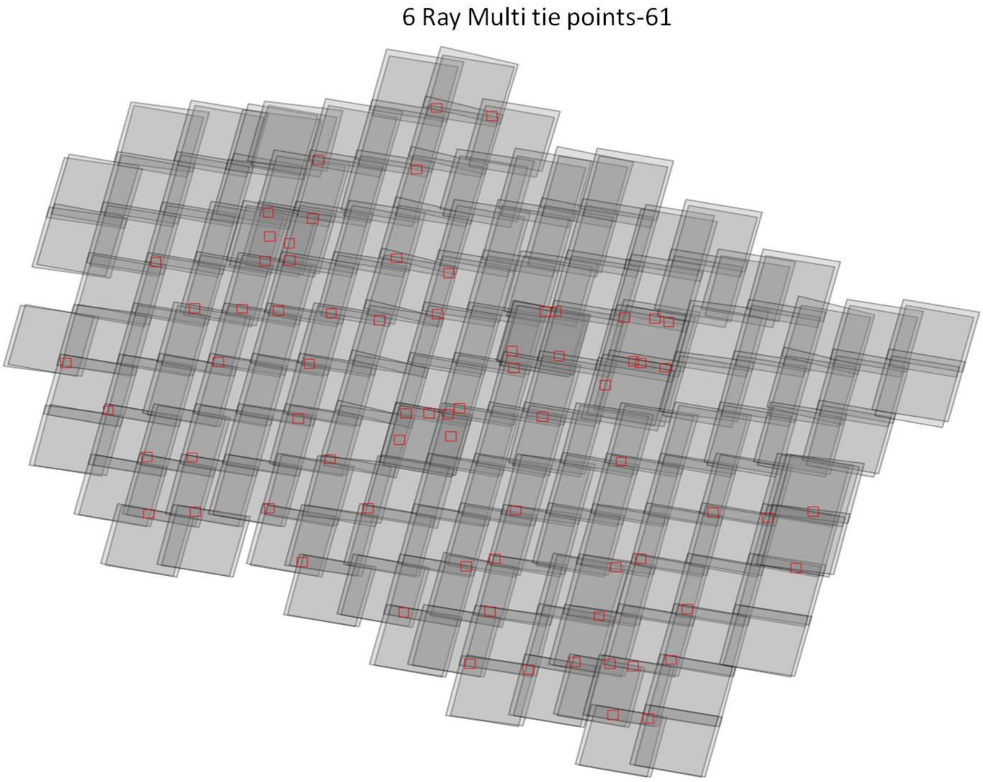


Fig XIII: Distribution of 6 ray multi tie points

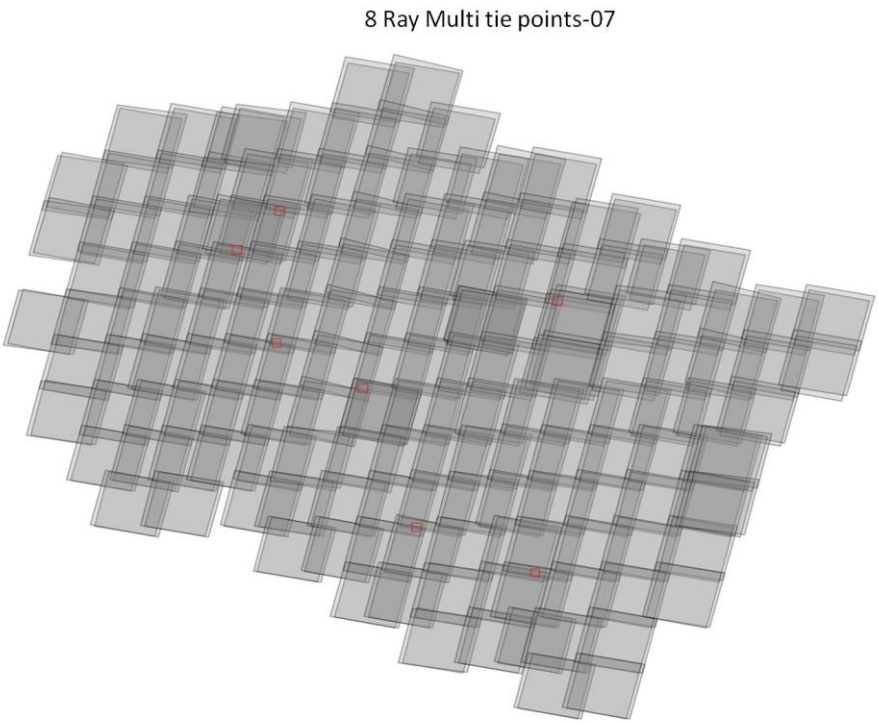


Fig XIV: Distribution of 8 ray multi tie points

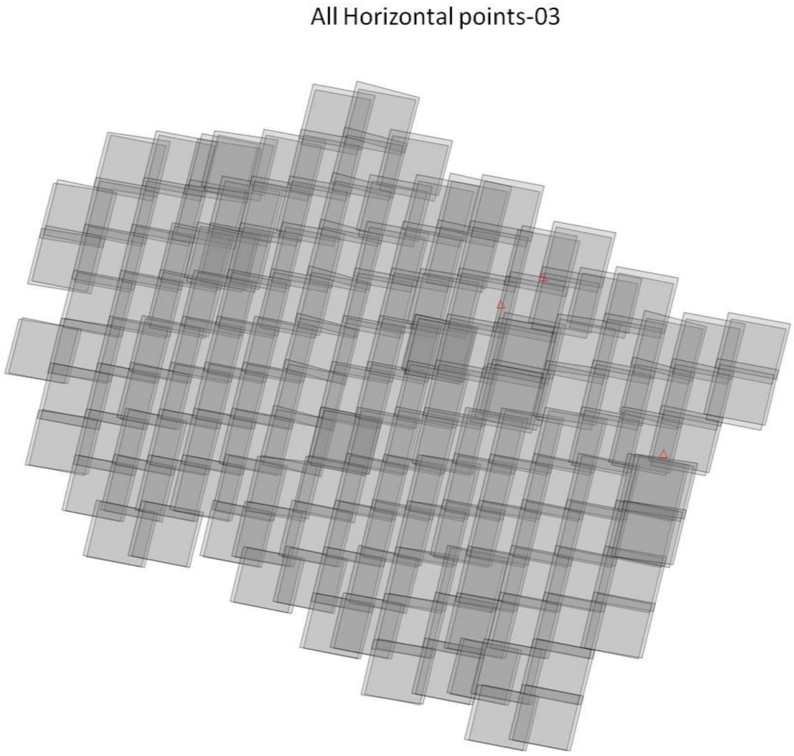


Fig XV: Distribution of all horizontal points

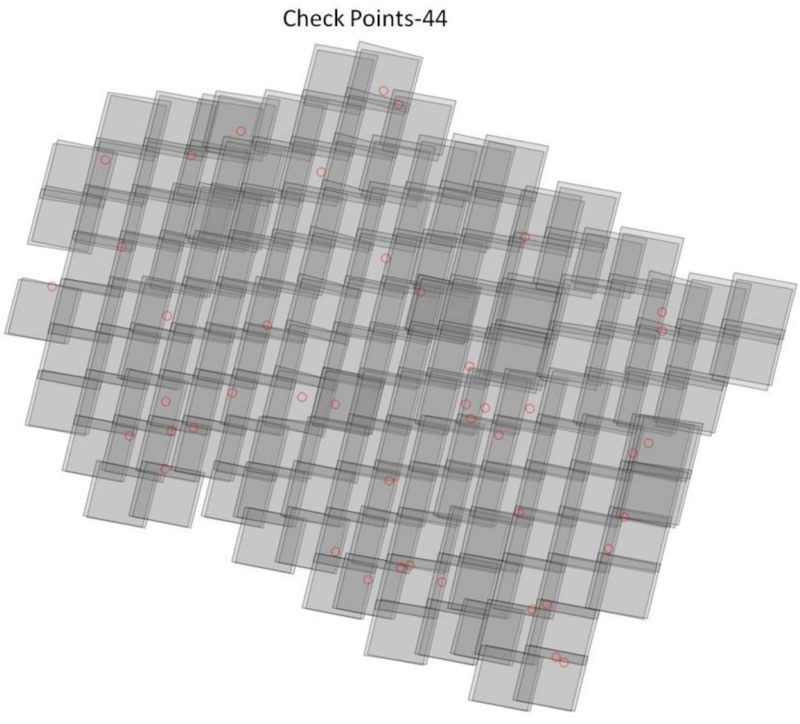


Fig XVI: Distribution of check points

5. RESULT:

It was observed that while using only RPC information for Cartosat-1 stereo data, the error in height was in the range 115.97 to 7555.979 m. However, after use of ground control points and triangulation adjustment, the Cartosat DEM becomes smooth and the error in height was reduced to 3 to 18m. The stereoscopic manual observation of the control point Z-RMSE is 3.602200.The distribution of manual stereo multi control points are showing in fig XVII. The block triangulation RMSE is 0.1694510 pixels. It included GCP points, multi tie points, auto tie points, check points, horizontal points. Control point RMSE is ground x: 1.8380150, ground y: 2.1355700, ground z: 3.4685709.image x: 0.9890115 and image y: 0.9726540. Check point RMSE is ground x: 2.7134039, ground y: 2.8416233, ground z:

4.473985, image x: 1.2325335, image y: 1.1424416. Fig XVIII is showing the RMSE of block. It was found that accuracy of contours generated from Cartosat-1 stereo data was very accurate and close to ground height. This Cartosat-1 stereo data can be used for height information generation at 10 m contour interval. The generated Digital elevation model of Uttarakhand is showing in fig XIX. The DEM generated from Cartosat-1 stereo data will be very much useful for topographic analysis in the field of water recourses, Landslide study, agriculture, urban planning etc.

RMSE: Executed for GCP + Horizontal + Check + Multi + Auto

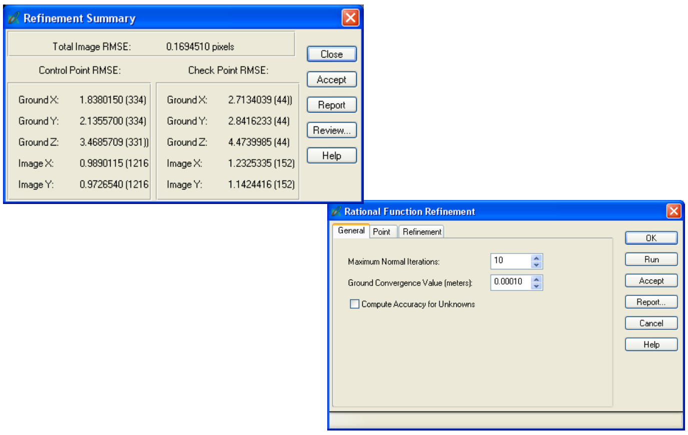


Fig XVIII: Refinement summary of Rout mean square error of the block

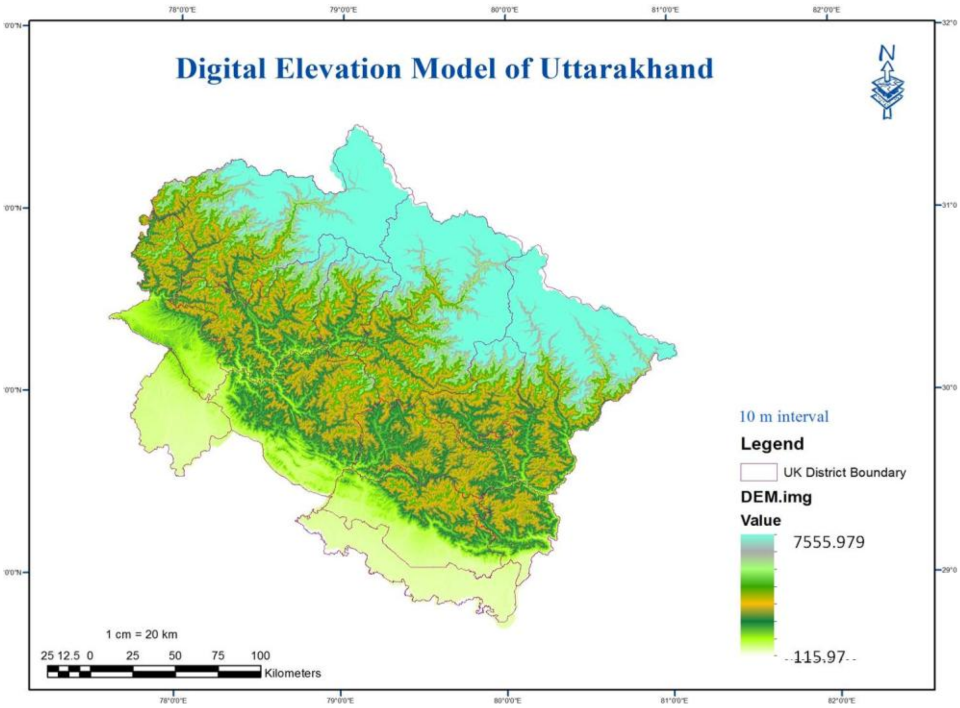


Fig XIX: DEM of Uttarakhand

6. CONCLUSIONS:

Cartosat-1 is among the first dedicated satellite mission for acquiring high-resolution stereo imagery with a capability for global coverage. With coarse DEM as basis, cartographic quality products better than 10 m is assured operationally. Also, preliminary exercises conducted using image restoration techniques ensure good radiometric quality for Cartosat-1 data products. Initial experiments with block adjustment approach conducted with LPS-11.0 s/w packages using stereo Ortho kit products promise generation of good quality DEM.

ACKNOWLEDGEMENTS:

Authors thankfully acknowledge the constant encouragement and support received from Dr. M. M. Kimothi, Director, USAC, Dr. K. P. Sharma, Group Head DIPFM, IIRS, Mr. P. K. Vaish, Scientist F, DIPFM, IIRS, Mr. K. Pandey Scientist C, DIPFM, IIRS, Mr. D. Sharma, Scientist SD, USAC, and special Thanks to Mr. D. Giri Babu, Scientist E, NRSC for his valuable suggestion and proper guidance.

REFERENCES:

(1) Srivastava, P. K. Gopala, K. Srinivasan, B. Amitabh, T. Trivedi P. S. and Nandakumar, R. 2006, *Cartosat-1 Data Products for Topographic Mapping,* ISPRS Commission-IV International Symposium on Geospatial Databases for Sustainable Development, Vol. 37, pp. 1357-1362.

(2) Nandakumar, R. Srinivasan, T. Gopala P. K. B. and Srivastava,P. K. 2005, *Data Products for Cartosat-1*, ISG Newslet-ter, Vol. 11, No. 2-3, pp. 18-24.

(3) Tao, C. V. and Hu, Y. 2001, *A Comprehensive Study of the Rational Function Model for Photogrammetric Processing,* Photogrammetric Engineering & Remote Sensing, Vol. 67, No. 12, pp. 1347-1357.

(4) Nadeem, A. Anjum, M. Ritesh, A. Jayaprasad, P. Pathan, Ajai, S. K. Singh, D. K. and Singh, A. K. 2007, *Extraction and Validation of Cartosat-1 DEM*, Journal of the In-dian Society of Remote Sensing, Vol. 35, No. 2, pp. 121-127.

(5) Ma, K. Di, R. and Li, R. 2003, *Rational Functions and Potential for Rigorous Sensor Model Recovery*, Photogrammetric Engineering & Remote Sensing, Vol. 69, No. 1, pp. 33-41.

(6) NRSC (National Remote Sensing Centre) 2012. *CARTOSAT1,* http://www.nrsa.gov.in/cartosat-1/html/home.html

(7) Poon, J. Fracer, C. S. and Zhang, C. 2007, *Digital Surface Models from High Resolution Satellite Imagery*, Photo-grammetric Engineering & Remote Sensing, Vol. 73, No. 11, pp. 1225-1232.

(8) Toutin, T. 2004. *Review article: Geometric processing of remote sensing images: models, algorithms and methods*. Int. J. Remote sensing, 20 May, 2004, Vol. 25, No. 10, 1893–1924.

(9) Spruyt, P., Kay, S., 2004 *Quality assessment test with Leica Geosystems ADS40: Digital Airborne Orthoimagery*. GIM International, June 2004, Vol. 18, Issue 6, pp. 35-37.