Slope generation using ArcGIS Model Builder a tool to check the accuracy of Digital Elevation Model (DEM) generated through photogrammetric block

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Abstract

The question of Digital Elevation Model (DEM) accuracy and interdependency of the height errors is closely connected with the question of the surface definition. In practice, the terrain surface is always an artificial surface that is consciously simplified and smoothed in order to obtain appealing or even usable products from the DEM. Thus DEM accuracy has to be defined with respect to the needs of the specific application. The accuracy of slope and all associated values is one important derived product from the DEM. It depends first of all in the height accuracy and on the resolution of DEM. But it also depends on the systematic parts of the height errors due to presence of systematic distribution like habitation, vegetation etc. Height errors normally distributed for a larger data set, but usually they show high local correlations. The consequence of ignoring systematic errors is an often unrealistic (i.e. too pessimistic for slope values) estimation of the quality of the derived data. DEMs with high cartographic quality (high resolution) show maximum correlation of errors with neighborhood pixels.

DEM generation using digital stereo-data in a digital photogrammetric environment by building a photogrammetric block with a RMS value adjusted to half of the pixel value of the satellite data/aerial data being used for the purpose gives a good quality product but it cannot be used directly for any product generation like ortho-image/photo without editing the same. Editing of DEM requires skilled professional involvement and extensive time. Verification of DEM quality after editing by visualization in 3D mode is also more pain staking job. Thus slope generation and representation of slope in a continuous color range with percentage mode or degree mode helps to identify the error associated with DEM. There are other methods like generation of drainage/stream from the DEM, which can be superimposed with the existing drainage layer to verify the accuracy of DEM.

In this paper it has been tried to prepare a tool using model builder of ArcGIS Ver.10.1, which was used to test the accuracy of DEM in a real time production mode project i.e. Space Based Information System for Decentralized Planning (SIS-DP) involving Cartosat-1 stereo pairs for Odisha state. This tool was very much helpful to check the accuracy of scene wise DEM generation in a real time production mode project as well as mosaicking of the DEMs up to the district/state level.

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Introduction

Several applications in earth and environmental sciences need information derived from the height data of the Digital Elevation Model (DEM). There is a special need for slope values, slope vectors and slope directions especially in water management, hydrology and environmental disaster prevention. A lot of research work has been done to define the accuracy of the DEM in terms of height errors, e.g. (Ackermann 1979), (Zhang, 1988), (Theobald, 1989). Frequently this is done by describing the root mean square (RMS) error of single DEM points. Another more sophisticated approach in order to obtain information to obtain the quality of DEMs is the use of Fourier Transformation (Makarovik, 1972), which especially allows to take into regard the periodical characteristics of height errors. But dealing with online projects having 300 and more DEM scenes (27.5k.m X 27.5k.m) with a resolution of 10mx10mt, it is really a difficult job to test the accuracy of DEM scenes by applying mathematical algorithms such as Fourier Transformation. Practically the quality checking scientist/engineer has to verify the scene by visualizing the sharp change in height which can be easily done by converting it into slope and applying a color scheme to visualize the slope in percentage or degree unit. The sharp change in height values in DEM can be detected and the DEM can be again edited in 3D environment to rectify the height errors. In order to simplify the task, ARC GIS ver.10.1 model builder has been utilized to create a tool to generate the slope, which took care of carrying out the job easily.

In this study, DEM was generated for the entire state of Odisha under a National level Project i.e. Space Based Information Support for Decentralized Planning (SIS-DP) using a controlled photogrammetric block of Cartosat-1 stereo digital data.

Objective

The objective of the study is to prepare a single photogrammetric block model of the State Odisha to generate a seamless Digital Elevation Model and Ortho image.

Study area

The entire State of Odisha bounded by the latitude and longitude as follows.

17^0 31′ N to 22^0 31′N

81^0 31‘E to 87^0 30’ E

Data used

- CARTOSAT – 1 Digital Stereo Pairs covering the entire State (397 Pairs)
- DEM chips provided by ISRO/DOS for the entire State to derive control points (X,Y&Z)
- DGPS observations of the four districts (Ganjam, khurdha, Cuttack and Keonjhar) created under NLRMP project to check the accuracy of DEM and ortho

H/W & S/W used

- One Core to duo Pentium –IV machine with 4GB RAM and NVDIA Quadro FX 3700 Graphics with 1GB RAM and two numbers of high end workstations with NVDIA graphics and 16GB RAM as well as 3D kit for DEM editing job.
- Leica Photogrammetric Suite (LPS) Version-2010 and 2011
- ARC GIS ver 10.1

Methodology

Odisha state was covered with 397 CARTOSAT-1 digital stereo pairs. The latest version i.e. LPS 2010 and 2011 was used for this project work. The photogrammetric block was prepared with the following block properties (Fig-1, Fig-2, & Fig-3).

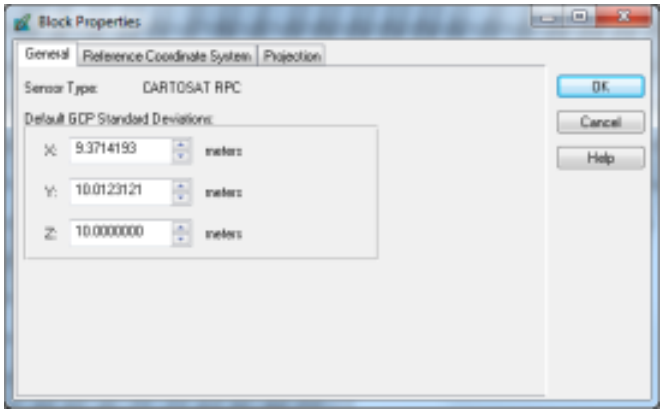


Fig1. General block properties

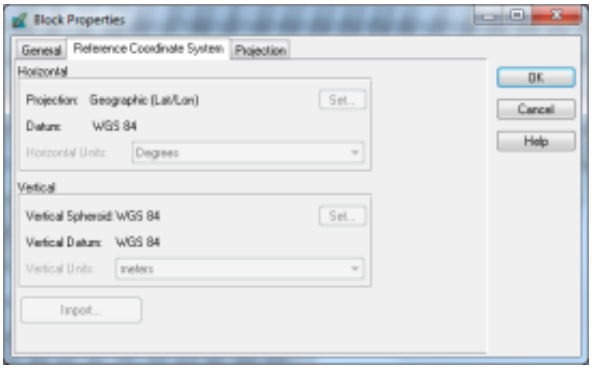


Fig2. Reference coordinate system used in the block setup

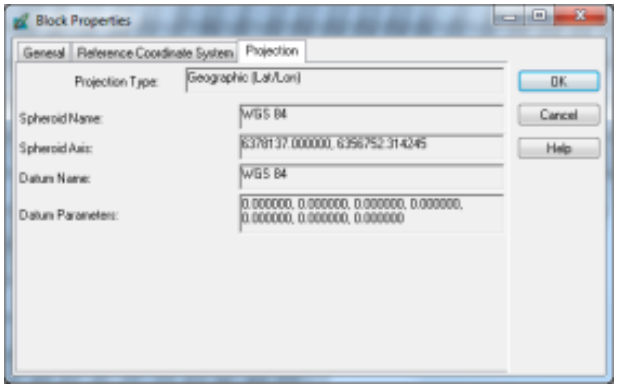


Fig3. Project used in the block setup

All the 397 stereo pairs were added to the block after verifying more than 20% side - lap and overlap with the neighboring pairs as well as other properties like cloud free data, staggering of the image, tilt of the image etc and finally a single photogrammetric block was prepared without any data gap(fig-4).

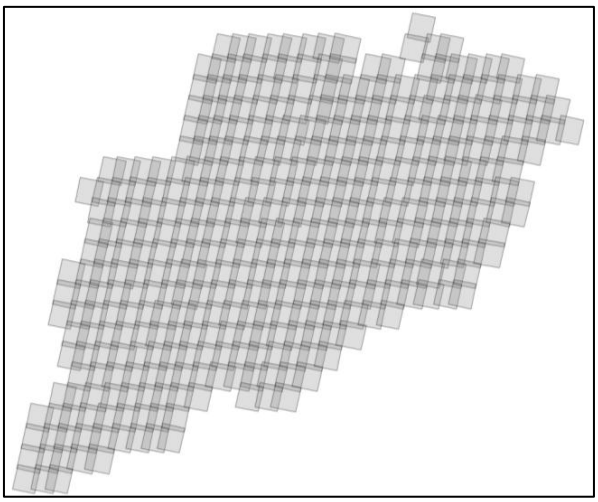


Fig4. Single Odisha Photogrammetric Block without any gap

Taking the volume of work into consideration the whole block was divided into three blocks for inputting manual tie points, auto tie points and control points. Well organized and distributed nine manual tie points were given in each pair of image, so that proper stitching of the pairs in all the sides with the neighboring pairs was confirmed. At completion of manual tie point as well as auto tie point, triangulation of the block was made, so that individual block was assured with RMS error within acceptable limit i.e. .5 pixels. The control points were given from the CARTO DEM and ORTHO chips provided by ISRO/DOS. Five control points were given per image pair, ensuring every scene has minimum two number of control points at each side and one in the middle of the scene. All the three blocks were merged into a single block and manual points, auto tie points and control points were imported to this block. The triangulation of the merged block was made and the RMS error was kept within .5 pixels in the first order polynomial. Distributed check points throughout the block were added (approximately 20 percent of the total number of control points) to verify the block accuracy. Again triangulation of the block was made keeping the RMS error within 0.5 pixels. The distribution of control points and the flow chart of methodology are shown in the following figures.

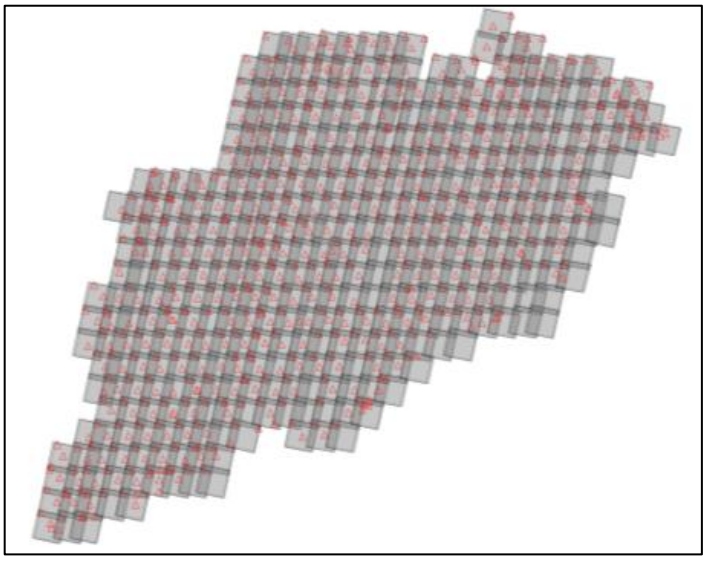


Fig5. Control Points distribution in the merged block

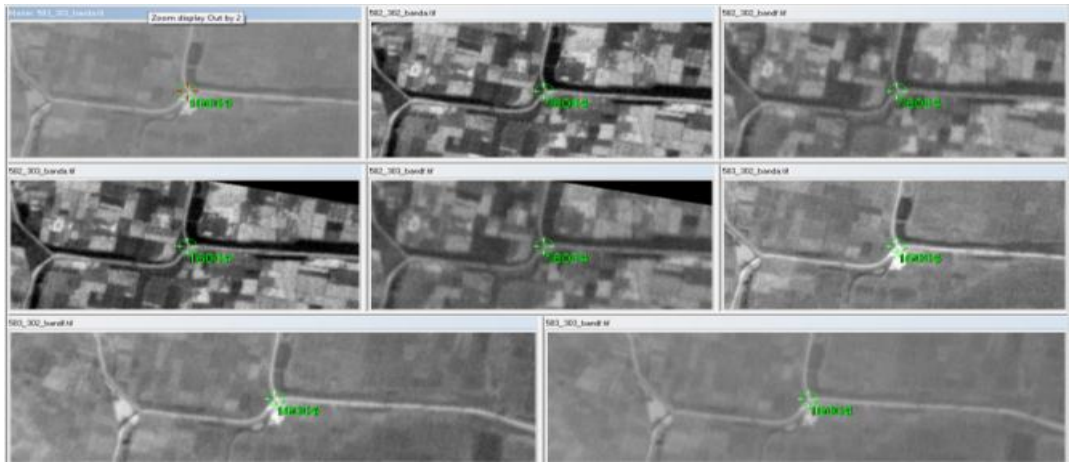
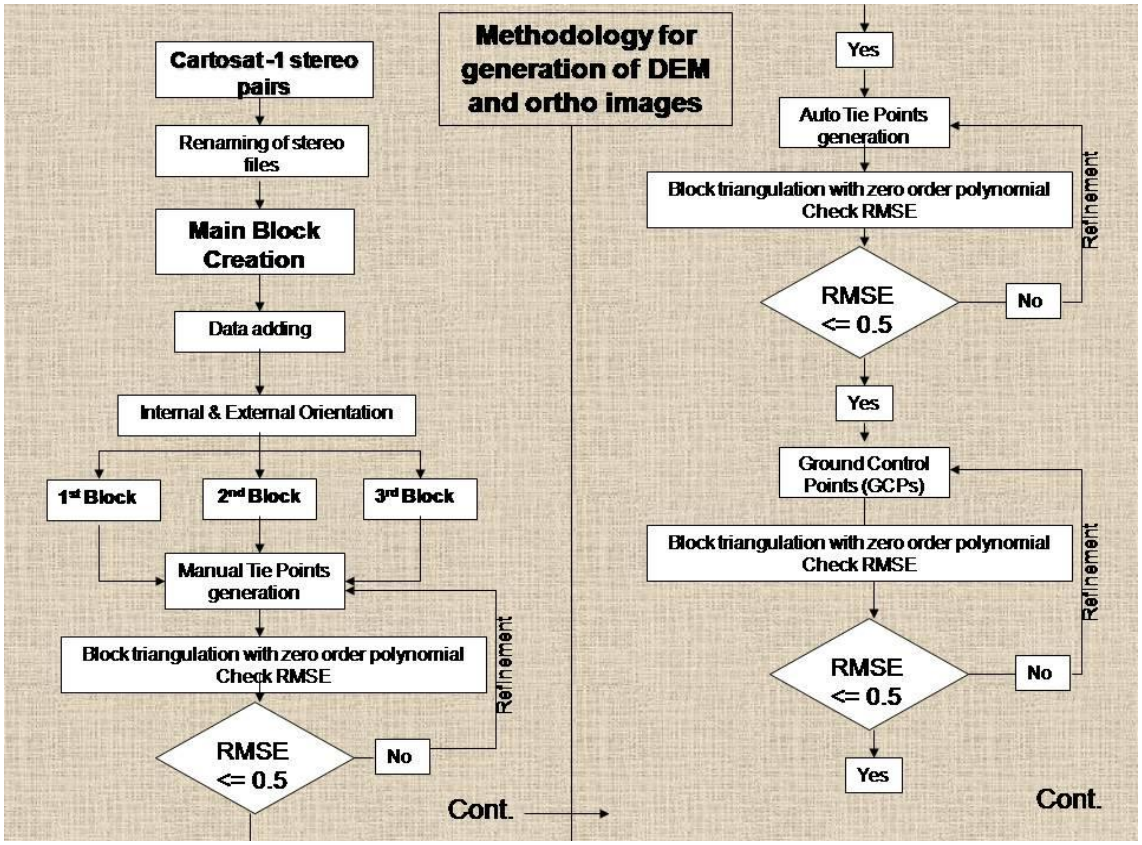


Fig.6- Placement of 8 ray control points

The detailed process flow is given in Fig-7 below.



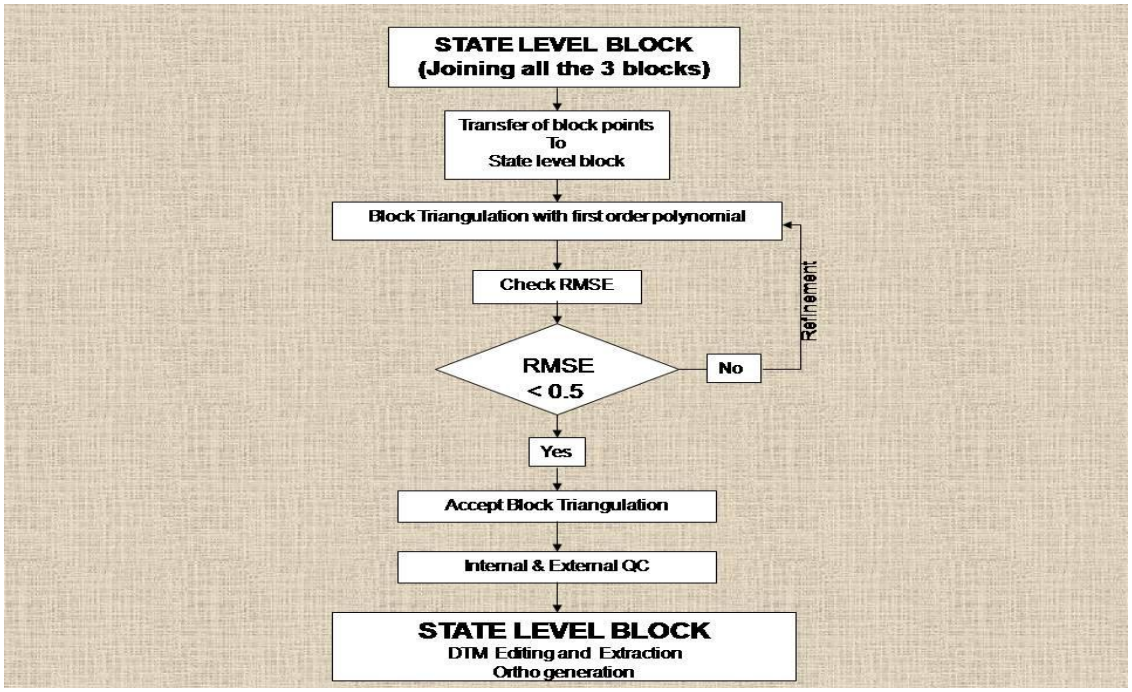
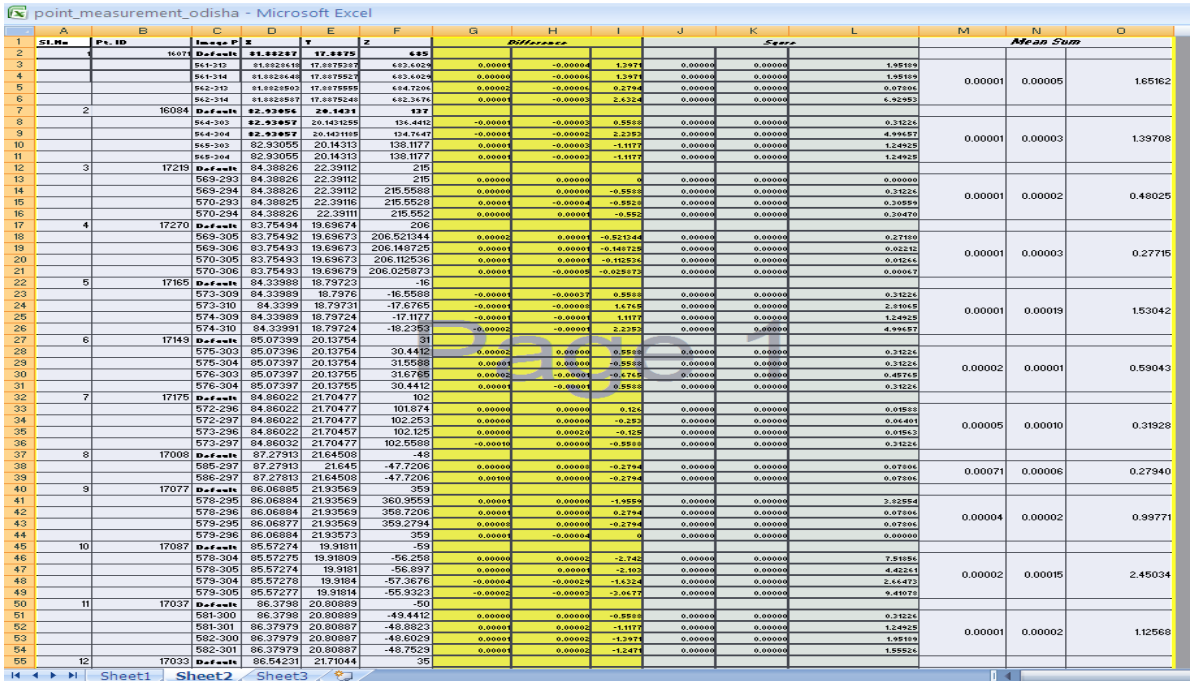


Fig7. Process flow diagram

The photogrammetric block was evaluated by the QC team of ISRO by taking random X, Y and Z measurements in the 3D editing environment. The measurement with total RMS is given in the table below (Fig-8.).



Sl.No	Pt. ID	Image P	X	Y	Z	Differences			Sqare			Mean Sum		
1														
2	1	16078	Default	81.88287	17.8875	685								
3			561-313	81.8828618	17.8875387	683.6029	0.00001	-0.00004	1.3971	0.00000	0.00000	1.95189			
4			561-314	81.8828648	17.8875927	683.6029	0.00000	-0.00006	1.3971	0.00000	0.00000	1.95189	0.00001	0.00005	1.65162
5			562-313	81.8828593	17.8875555	684.7206	0.00002	-0.00006	0.2794	0.00000	0.00000	0.07806			
6			562-314	81.8828587	17.8875248	682.3676	0.00001	-0.00003	2.6324	0.00000	0.00000	6.92953			
7	2	16084	Default	82.93056	20.1431	137									
8			564-303	82.93057	20.1431255	134.4412	-0.00001	-0.00003	0.5588	0.00000	0.00000	0.31224			
9			564-304	82.93057	20.1431185	134.7647	-0.00001	-0.00002	2.2353	0.00000	0.00000	4.99457	0.00001	0.00003	1.39708
10			565-303	82.93055	20.14313	138.1177	0.00001	-0.00003	-1.1177	0.00000	0.00000	1.24925			
11			565-304	82.93055	20.14313	138.1177	0.00001	-0.00003	-1.1177	0.00000	0.00000	1.24925			
12	3	17219	Default	84.38826	22.39112	215									
13			569-293	84.38826	22.39112	215	0.00000	0.00000	0	0.00000	0.00000	0.00000			
14			569-294	84.38826	22.39112	215.5588	0.00000	0.00000	-0.5588	0.00000	0.00000	0.31224	0.00001	0.00002	0.48025
15			570-293	84.38825	22.39116	215.5528	0.00001	-0.00004	-0.5528	0.00000	0.00000	0.30559			
16			570-294	84.38826	22.39111	215.552	0.00000	0.00001	-0.552	0.00000	0.00000	0.30470			
17	4	17270	Default	83.75494	19.69674	206									
18			569-305	83.75492	19.69673	206.521344	0.00002	0.00001	-0.521344	0.00000	0.00000	0.27180			
19			569-306	83.75493	19.69673	206.148725	0.00001	0.00001	-0.148725	0.00000	0.00000	0.02212	0.00001	0.00003	0.27715
20			570-305	83.75493	19.69673	206.112536	0.00001	0.00001	-0.112536	0.00000	0.00000	0.01266			
21			570-306	83.75493	19.69679	206.025873	0.00001	-0.00005	-0.025873	0.00000	0.00000	0.00067			
22	5	17165	Default	84.33988	18.79723	-16									
23			573-309	84.33989	18.7976	-16.5588	-0.00001	-0.00037	0.5588	0.00000	0.00000	0.31224			
24			573-310	84.3399	18.79731	-17.6765	-0.00001	-0.00008	1.6765	0.00000	0.00000	2.81045	0.00001	0.00019	1.53042
25			574-309	84.33989	18.79724	-17.1177	-0.00001	-0.00001	1.1177	0.00000	0.00000	1.24925			
26			574-310	84.33991	18.79724	-18.2353	-0.00002	-0.00001	2.2353	0.00000	0.00000	4.99457			
27	6	17149	Default	85.07399	20.13754	31									
28			575-303	85.07396	20.13754	30.4412	0.00002	0.00000	0.5588	0.00000	0.00000	0.31224			
29			575-304	85.07397	20.13754	31.5588	0.00001	0.00000	-0.5588	0.00000	0.00000	0.31224	0.00002	0.00001	0.59043
30			576-303	85.07397	20.13755	31.6765	0.00002	-0.00001	-0.6765	0.00000	0.00000	0.45745			
31			576-304	85.07397	20.13755	30.4412	0.00001	-0.00001	0.5588	0.00000	0.00000	0.31224			
32	7	17175	Default	84.86022	21.70477	102									
33			572-296	84.86022	21.70477	101.874	0.00000	0.00000	0.126	0.00000	0.00000	0.01588			
34			572-297	84.86022	21.70477	102.253	0.00000	0.00000	-0.253	0.00000	0.00000	0.06401	0.00005	0.00010	0.31928
35			573-296	84.86022	21.70457	102.125	0.00000	0.00020	-0.125	0.00000	0.00000	0.01563			
36			573-297	84.86032	21.70477	102.5588	-0.00010	0.00000	-0.5588	0.00000	0.00000	0.31224			
37	8	17008	Default	87.27913	21.64508	-48									
38			585-297	87.27913	21.645	-47.7206	0.00000	0.00008	-0.2794	0.00000	0.00000	0.07806	0.00071	0.00006	0.27940
39			586-297	87.27813	21.64508	-47.7206	0.00100	0.00000	-0.2794	0.00000	0.00000	0.07806			
40	9	17077	Default	86.06885	21.93569	359									
41			578-295	86.06884	21.93569	360.9559	0.00001	0.00000	-1.9559	0.00000	0.00000	3.82554			
42			578-296	86.06884	21.93569	358.7206	0.00001	0.00000	0.2794	0.00000	0.00000	0.07806	0.00004	0.00002	0.99771
43			579-295	86.06877	21.93569	359.2794	0.00008	0.00000	-0.2794	0.00000	0.00000	0.07806			
44			579-296	86.06884	21.93573	359	0.00001	-0.00004	0	0.00000	0.00000	0.00000			
45	10	17087	Default	85.57274	19.91811	-59									
46			578-304	85.57275	19.91809	-56.258	0.00000	0.00002	-2.742	0.00000	0.00000	7.51856			
47			578-305	85.57274	19.9181	-56.897	0.00000	0.00001	-2.103	0.00000	0.00000	4.42261	0.00002	0.00015	2.45034
48			579-304	85.57278	19.9184	-57.3676	-0.00004	-0.00029	-1.6324	0.00000	0.00000	2.66473			
49			579-305	85.57277	19.91814	-55.9323	-0.00002	-0.00003	-3.0677	0.00000	0.00000	9.41078			
50	11	17037	Default	86.3798	20.80889	-50									
51			581-300	86.3798	20.80889	-49.4412	0.00000	0.00000	-0.5588	0.00000	0.00000	0.31224			
52			581-301	86.37979	20.80887	-48.8823	0.00001	0.00002	-1.1177	0.00000	0.00000	1.24925	0.00001	0.00002	1.12568
53			582-300	86.37979	20.80887	-48.6029	0.00001	0.00002	-1.3971	0.00000	0.00000	1.95189			
54			582-301	86.37979	20.80887	-48.7529	0.00001	0.00002	-1.2471	0.00000	0.00000	1.55526			
55	12	17033	Default	86.54231	21.71044	35									

The random measurement has given the total RMS in meters as .85mt. which is considered to be finest achievable value taking the spatial resolution of CARTOSAT-1 into consideration. The Leica Terrain Format (LTF) DEM was generated with 10mt. spatial resolution for carrying out editing further to remove the floating/digging mass points generated through the process. The vector DEM was converted to raster DEM with same spatial resolution of 10mx10m. Individual scene wise raster DEM as well as

mosaiced DEM up to District/State level were verified with slope tool generated using ARC GIS ver. 10.1 model builder. The tool is given below.

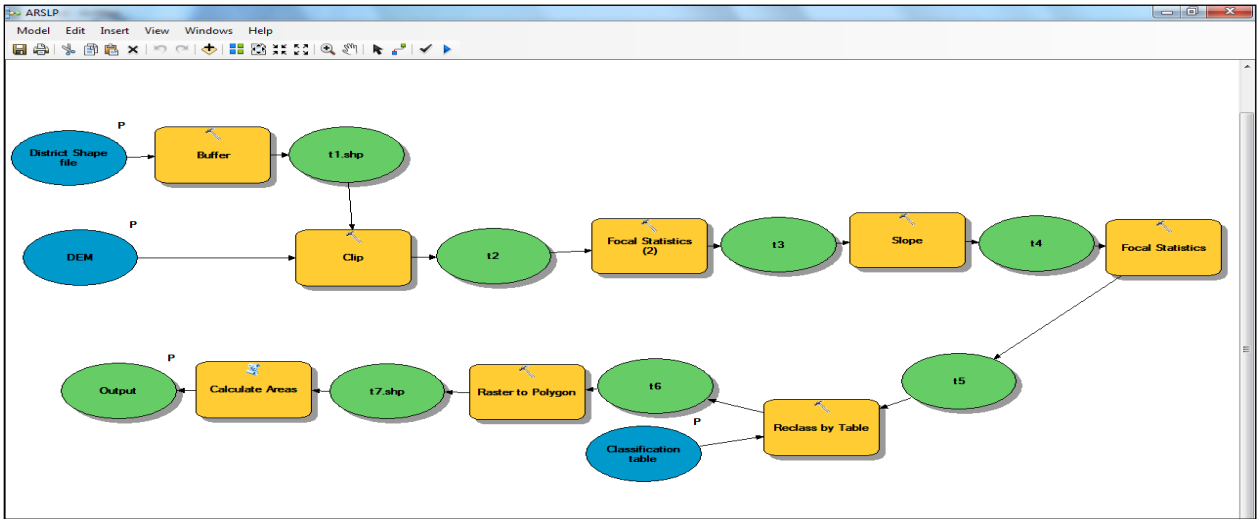
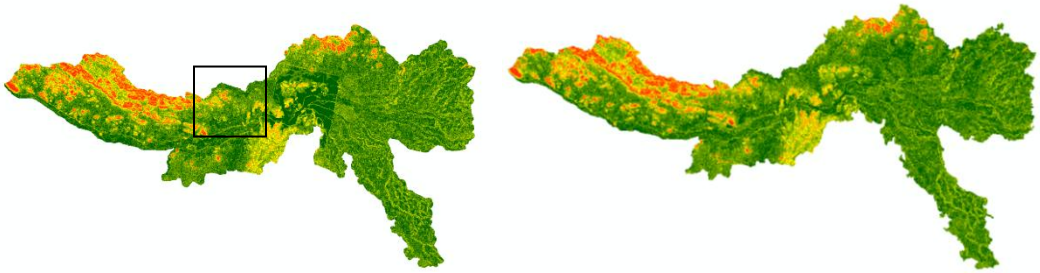


Fig.9 Slope tool used for accuracy checking of DEM

District wise mosaic DEM converted to vector slope was verified by visualizing through a color schema (percentage range) and where errors were observed the vector DEMs were re-edited to remove the errors.

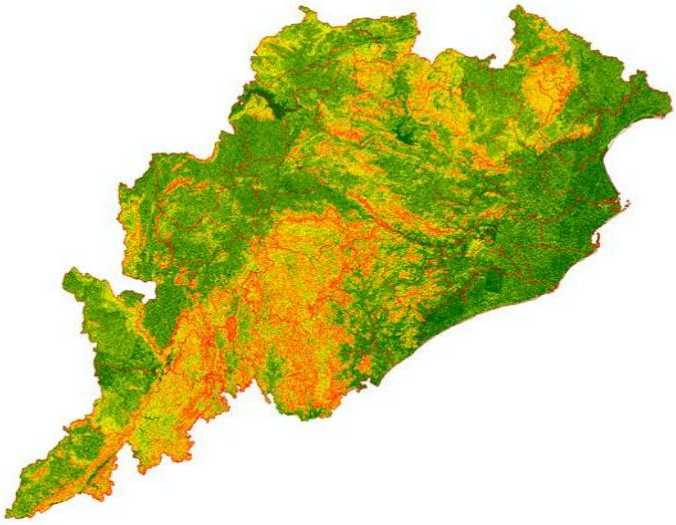


Slope in percentage		Value	Colour
From	To		
0	1	1	
1	3	2	
3	8	3	
8	15	4	
15	30	5	
35	45	6	
ABOVE 45		7	

Fig.10 Slope of Katak District with error and without error

Results and Discussion

The preparation of a seamless photogrammetric block involving 397 digital stereo pairs and triangulating the same is a huge experience gained by the State centre. The accuracy achieved in the order of 1m. in X,Y and Z ensures stable orbital geometry of the CARTOSAT-1 mission. The Digital Elevation Model (DEM) generated under this project with 10 m. spatial resolution is considered to be the first of its kind which will provide contour and slope layers of the State. These layers will serve as a major input layers for integration with other resource layers like Land use / Land cover, Geomorphology, Soil etc in GIS environment to prepare working plans for watersheds involving the lowest administration of the Country i.e. Pachayats envisaged under this project. This will act as a base layer for coming years till ISRO/DOS comes out with fine resolution stereo capability mission in space. The mosaiced slope layer for the Odisha State generated using the slope tool above in the ARC GIS ver. 10.1 will be the one of the most important derived layer from DEM.



Slope in percentage		Value	Colour
From	To		
0	1	1	
1	3	2	
3	8	3	
8	15	4	
15	30	5	
35	45	6	
ABOVE 45		7	

Fig. 11 Slope layer for the State of Odisha generated using ARC GIS ver. 10.1

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The authors sincerely thank all the Scientific, technical, engineering and administrative staff of ORSAC, Bhubaneswar, RRSC-East, Kolkata and NRSC, Hyderabad whose contribution to this project in many ways enabled to complete the photogrammetric block of Odisha in time as well as to complete the DEM and ortho for carrying out resource layer generation of the State. The authors thank the Chairman ISRO/DOS and Chief Secretary and Chief Development Commissioner to Govt. of Odisha-cum-Chairman, ORSAC for their support to this project.

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