Assessment of New High- Resolution SkySat Satellite Imagery for Producing Large Scale Map

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ABSTRACT: In this study the capabilities of very high resolution VHR satellite images for producing large scale maps were evaluated for an area in Egypt. Data used in this study were obtained from skysat imagery. The SkySat Pansharpened0.8m and Multispectral1m scene products were orthorectified, pan sharpened, and color-corrected (using a color curve). A 4-band imagery was acquired on November 2017 and covered an area of 15× 8km with spatial resolution of 0.8m. An investigation of individual 4-band was carried out to find out the potential of the information content in pansharpened SkySat image in producing large scale mapes. Twenty Check Points (CPs) were taken as the source of supplementary data to be used in this respect for checking the geometric accuracy of the orthorectified image. The coordinates of the CPs were determined using **GPS Topcon HiPer V** GNSS receiver with horizontal accuracy of (10mm + 1ppm). The geometric accuracy was assessed using the ground and image coordinates. the RMSE found to be $\sigma\Delta E=\pm0.966$m and, $\sigma\Delta N=\pm1.094$m for easting and northing directions with total RMSE = ±1. 459m. According to American Society for Photogrammetry and Remote Sensing (ASPRS) standards it is found that skysat images can be used for producing or updating large scale map of **1:3000** and smaller scales depending on the accuracy required in the map output. It can be concluded that high resolution satellite imagery skysat data can be used in various applications within a national mapping agency in a country like Egypt.

Introduction: Remote sensing technology and satellite imagery have been investigated and used in a different field since the eighteenth decade. It was used successfully in different fields such as agriculture, mining, disaster management, meteorology, forestry and geographic information systems. For example, it was used to explore the variety types of vegetation, oil spills, wetlands and soil types [4].

High resolution satellite(sub-meter) sensors are considered one of the excellent progressions which explore new applications of remote sensing data, one of these is the large-scale map. SkySat was launched by Space Imaging in 2017.It is including in the list of commercial satellite which took images with a meter and sub-meter pixel size resolution. EROS A1 (2000), QuickBird (2001), IKONOS (2006), orbview(2008), Rapied Eye(2008) ,WorledView(2016), and a number of other satellites have followed it in taking images about the same or less pixel sizes[5]. Maps are date incisive evidence of a locality conserving the nations of Earth's surface in their production time. Production of maps are compiled in different scales [1], with respect to the spatial size of the features to be registered on the maps and the range of the area of interest. The larger the range of the area to be represented on a map is probational to, the smaller the size of the features can be described and vice versa [1]. The small-scale maps cover extensive areas such as a region, county, a whole country or even a group of countries on a single sheet. On the other hand, large scale maps, are produced for many purposes with a full particulars of information content of the studying area or specific area. Mostly the Large scale- maps are used in urban studies for different objectives. The cadaster maps and digital land information databases about real estate utilities and ownership where right realizations about borders of neighboring land portion is required are prepared in larger scales [2]. Producing, updating and revision of large scale-maps require accurate information's with acceptable spatial precision [1]. Before launching of high resolution sensors, the only source for producing these maps was land surveying or aerial photography which are costly and time consuming. With the help of new high spatial resolution satellite images, producing, and updating of large scale maps became much easier, faster, and cheaper than before.

SkySat Ortho Scene Characteristics Overview: The ortho scene product enables users to easy create imagery by joining and merging the chosen SkySat ortho scenes to cover the specific area required [Figure1]. The product of SkySat ortho scene is orthorectifiesd and is designed for a variety of usage that require imagery with a cartographic projection and accurate geolocation. The image was prepared by removing distortions caused by terrain and can be used for cartographic purposes, [Table1]. SkySat ortho scene product contains visual, panchromatic, analytic, and pansharpened multispectral imagery that is examined and in a raw digit's format. It is sensor- and geometrically-corrected and projected to a cartographic map projection. The geometric correction uses fine Digital Elevation Models (DEMs) with a post interval range between 30 and 90 meters. Ground Control Points (GCPs) are used in the creation of every image and the accuracy of the product will vary from region to region based on available GCPs

Table [1] Specifications of SkySat Imagery.

SkySat Ortho Scene Product Attributes	
Scene Product	**Description**
1- Product Format and Components	Image File – GeoTIFF format Metadata File – JSON format Rational Polynomial Coefficients – Text File -UDM File – GeoTIFF format
2- **Information** Product	SkySat Satellites have three cameras per satellite, which capture overlapping strips. Each of these strips contain overlapping scenes. One scene is approximately 3199m x 1349m
3- Spectral Bands	Blue: 450 - 515nm Green: 515 - 595nm Red: 605 - 695nm NIR: 740 - 900nm Pan: 450 - 900nm
4-Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model. Orthorectification uses GCPs and fine DEMs (30m to 90m posting).
5- Horizontal Datum	WGS84
6- Map Projection	UTM
7- Geometric Accuracy	<10m RMSE
8-Ground Sample Distance	0.8m (At reference altitude 600km)
9-Pixel Size (Orthorectified)	0.8m

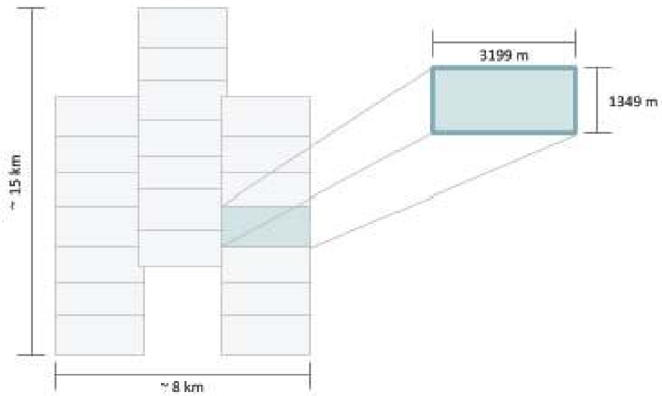

Figure (1) The Capture of Imagery

The Capabilities of SkySat: Since data again of the SkySat constellation [Figure 2] from seven satellites, concentration was made by SkySat team on processing this high-resolution data which were accessible and available via cloud-based data infrastructure. After four months of heavy lifting object from spacecraft, data pipeline and product teams, they delighted to declare that sub one-meter, high-resolution imagery is now accessible and available through the Planet SkySat Center [3]. The unparalleled ability of the SkySats imagery made it possible to offer a range of new high-resolution (hi-res) products to the marketing mix. All SkySats collect imagery with sub-meter resolution (0.8meter GSD), in the Red, Green, Blue, Near Infrared, and Panchromatic bands. Due to their unique push-frame architecture, the cost reaches 100$ per 1 km square to obtain SkySats image. SkySats can also capture full motion video with frame rates as high as 50hz and durations longer than 2 minutes. [3]

Figuer2Illustrationf Four of High-Resolution SkySat imagery Satellite Developed

Study Area: The study area lies in new capital city near Cairo Egypt which is located between 30 03 13.74'' and 29 55 22.33'' N latitudes and 31 40 02.88'' and 31 45 19.08'' E longitudes. The area covers about 15X 8km. The study area is characterized by nearly hilly terrain as shown in Figure 3

Subset: Subset is a process used when the image has to be reduced in size or a sample portion of the image need to be used for carrying out analysis. The chosen area lies within 21 satellite images and were provided by a commercial data provider [Figure1]. The skysat satellite imagery was larger than the area of interest AOI. The AOI was extracted by using subset tool. One of the advantages of performing the subset step is that after extracting the region of interest from the larger image, the geometric accuracy assessment processing will be done for the required area only and the calculation of ΔE, ΔN, and the total RMSE will be from the AOI only and not the whole images.

Methodology: The procedure that will be followed in this assessment is to compare the coordinates of 20 points well identified in both the field and skysat images the first set of coordinats were observed using **GPS Topcon HiPer V** GNSS receiver and the second set from the image using ERDAS Imagine 9.2 software. Data from, Skysat images acquired in November 2017 were used in this study. A subset area of 5 X5 km was used from these Skysat images with 0.8 m spatial resolution (according to the data Image property). All visible bands were included in the analysis. Remote sensing image processing was performed and inspected using ERDAS Imagine 9.2

Field Work: According to the American Society for Photogrammetry and Remote Sensing (ASPRS) at least twenty check points are recommended based on the tested area as the source of data to be used in this respect for image geometric comparison [Table 2]. The Selected CPs on the ground were located to be clearly visible and accurately identified in both the image and the field. For example, points of roads intersection, corners of isolated features such as building, houses and intersection of paths or streams. A relative positioning technique was used to obtain the grid coordinates of the twenty selected points, located in tested area.

Table2Recommended Number of Check Points Based on Area [6]

Project Area (Square Kilometers)	Horizontal Testing	Vertical Testing (not clearly-defined points)		
	Total Number of Static Horizontal Check Points (clearly-defined points)	Number of Static Vertical Check Points in NVA	Number of Static Vertical Check Points in VVA	Total Number of Static Vertical Check Points
≤500	20	20	0	20
501-750	25	20	10	30
751-1000	30	25	15	40
1001-1250	35	30	20	50
1251-1500	40	35	25	60
1501-1750	45	40	30	70
1751-2000	50	45	35	80
2001-2250	55	50	40	90
2251-2500	60	55	45	100

The field data were collected using Topcon HiPer V GNSS receiver. With Kinematic check points system.Topcon HiPerV Global Navigation Satellite System (GNSS) receiver is a multiple-frequency GNSS receiver, which is flexible, powerful, and reliable. Table3 shows the Specifications of Topcon HiPer V GNSS Receiver.

Table 3 Specifications of Topcon HiPer V

1-Number of Channels	226 Tracking Channels Universal Tracking Technology capable of tracking up to 112 satellites
2-Tracked Signals	*GPS Signals of L1 CA, L1/L2 P-code, L2C. *GLONASS Signals of L1/L2 CA, L1/L2 P-code. *Satellite-Based Augmentation Systems of WAAS, EGNOS, QZSS, and MSAS
3-Static	L1 only H: 3mm + 0.8ppm V: 4mm + 1ppm L1+L2 Horizontal = 3mm + 0.1ppm (1) Vertical = 3.5mm + 0.4ppm (1)
4-RealTime Kinematic (RTK)	L1+L2 H: 10mm + 1ppm V: 15mm + 1ppm
5-Differential GPS (DGPS)	Less than 0.5m (1.6 foot)
6-communication	WIRELESS COMMUNICATION
7- Shock Rating	2m (6.56ft.) pole drop
8- Operating Temperature	HiPer V GNSS Receiver (with battery) = ………………… =-40to+149F (-40 to +65°C) BDC58 Battery = -4 to +149°F (-20 to +65°C) Radio/GSM modems = -4 to +131°F (-20to+55°C)
9- Humidity	100%, condensing
10- Size	7.24" Diameter x 3.74" Height (184mm Diameter x 95mm Height)
11- Weight	HiPer V GNSS Receiver 2.20lb.(1.00kg) BDC70 Battery = 6.9 oz. (195g)

Reference station that was used in this study is located on the top of a hill near the area of interest, the known coordinates of reference station are in (U.T.M) WGS84 ellipsoid:

Latitude = 3316552.55”N

Longitude = 376208.9” E

Ellipsoidal Height = 381.031 m.

The reference station was occupied by one **Topcon HiPer V** GNSS receiver, while the collection of the twenty chosen points were by RTK method. The maximum baseline distance between the reference station and the selected **(CPs)** was about 4Km. The recorded observations of the twenty check points and reference station, were imported and processed through MAGNET Field software. The processing parameters were by using broadcast ephemeris and, cut off angle of 15º, troposphere model of Hopfield, and fix ambiguity up to50 km. Table4 shows the obtained coordinates of the twenty**(CPs)**, inWGS84 UTM_{36} coordinate system.

Table4 WGS U.T.M_{36}Ground Coordinates of Testing Points

U.T.M_{36}Ground Coordinates[m]				
NO.	Code	Easting	Northing	Elevation
1	f1	377296.02	3319466.08	326.4736
2	f2	377447.59	3320297.85	319.6098
3	g1	377345.06	3320502.27	318.741
4	f3	376594.81	3320322.37	322.0946
5	p1	376744.6	3320484.34	321.4341
6	p2	376831.52	3320482.96	320.955
7	p3	377494.47	3319721.81	323.8551
8	r1	376421.75	3320004.16	324.7032
9	r2	375955.85	3319486.91	338.0054
10	m1	375616.23	3319601.78	346.9117
11	m2	375598.44	3319688.71	346.8833
12	r3	375463.86	3319579.28	335.3441
13	r4	375589.29	3320114.16	330.7785
14	r5	376309.75	3320165.79	325.3879
15	p4	376420.73	3319831.42	328.0425
16	p5	376344.53	3320709.47	321.0457
17	p6	376359.76	3320774.59	319.8917
18	r6	376213.92	3320400.4	329.0696
19	G2	377368.6414	3320501.331	318.641
20	j1	377369.4022	3320462.024	318.691

The coordinates of the 20 points were collected from SkySat satellite mosaic image through Inquire Cursor tool at ERDAS IMAGIN 9.2 Software. These coordinates were compared with GPS coordinates. The CP_s Because of time difference between images capture and field measurements, some difficulties were encountered in detecting the features on the image and in finding the relevant CP's in field. Therefore, several trails were conducted to find the best pixels which have the same grey scale values and represent the same features. In this process, it was very beneficial to use the brightness or darkness of adjacent pixels for locating accuracy. Table5 show, image UTM_{36} coordinates for chosen features. As mentioned before, the area of interest was open desert areas with different land cover types such as, high-way, communication and electricity transmission lines and large residential areas under construction. The check points which were measured on the image are shown in [Figure3]

Table 5 Image UTM_{36} Coordinates For CP_S

		UTM_{36} Image	Coordinates
NO.	Code	Easting	Northing
1	f1	377296.177	3319465.844
2	f2	377448.2065	3320297.505
3	g1	377345.2474	3320502.662
4	f3	376594.1027	3320321.343
5	p1	376744.8642	3320482.741
6	p2	376832.1005	3320482.755

7	p3	377494.7409	3319721.72
8	r1	376421.5322	3320002.702
9	r2	375956.4413	3319484.864
10	m1	375618.591	3319602.785
11	m2	375599.7616	3319689.26
12	r3	375463.7086	3319578.947
13	r4	375589.8715	3320114.283
14	r5	376308.4294	3320167.538
15	p4	376422.0394	3319829.708
16	p5	376345.9613	3320708.2
17	p6	376360.1625	3320774.134
18	r6	376212.0494	3320401.873
19	g2	377369.2754	3320500.951
20	j1	377368.895	3320461.897

Figure (3) Location of The20 Check Points

Evaluation of Geometric Accuracy: For geometric accuracy assessment, the SkySat satellite mosaic image have been produced first. Then, check points (CP's) were selected from mosaic images and finally, ground and image coordinates were measured and compared as in Table 6 we can see that $\sigma\Delta E = \pm 0.9663$m and $\sigma\Delta N = \pm 1.0940$m so the total R.M.S.E =± 1.459m.

Table 6 Comparison Between Ground and Image Coordinates for CP_S

ΔE	ΔN	$ΔE^2$	$ΔN^2$
-0.15703	0.235781	0.024659	0.055593
-0.61648	0.345078	0.380053	0.119079
-0.18742	-0.39226	0.035127	0.153873
0.707266	1.027266	0.500225	1.055275
-0.26422	1.599219	0.069812	2.557501
-0.58047	0.204844	0.336944	0.041961
-0.27094	0.089687	0.073407	0.008044
0.217812	1.457812	0.047442	2.125216
-0.59125	2.04625	0.349577	4.187139
-2.36098	-1.00484	5.574212	1.009711
-1.32164	-0.55031	1.746735	0.302844
0.151406	0.332969	0.022924	0.110868
-0.58148	-0.12343	0.338124	0.015237
1.320625	-1.74812	1.74405	3.055941
-1.30938	1.711875	1.714463	2.930516
-1.43125	1.270001	2.048477	1.6129
-0.4025	0.455625	0.162006	0.207594
1.870625	-1.47312	3.499238	2.170097
-0.63398	0.38039	0.401937	0.144697
0.507188	0.126797	0.25724	0.016077
RMSE(E)=	0.9663m		
RMSE(N)=	1.0940m	RMSE=1.459m	

Production Large Scale Map: In order to achieve the planimetric features for mapping from satellite image data collection, all the objects, that are of relevance for the specific map scale, have to be particular and located with adequate accuracy. The realizability of suitable topographic features in satellite images depends on a variety of elements. The potential of planimetric mapping from satellite image data has been subordinate to many advanced experiments studies [10]. Most of the investigations focus on the sensors which so far presented the highest resolution for this purpose. Besides the usual standard for the choosing of map scales, in the case of satellite image maps the realizability of image data has to be respected. It is a part of the technical parameters of the imaging sensor and the structural and spectral properties of the topography as well. According to practical experience the yielding map quality is acceptable if the R.M.S.E is within the allowable values for corresponding map scale. These values are shown in the following Table 7. It shows the appropriate largest map scales for different value of R.M.S.E. Therefore, for a total R.M.S.E = 1.459 m large scale map up to 1:3000 can be produced [12]. According to table 7 from the American Society for Photogrammetry and Remote Sensing (ASPRS) and Table 8 one can get horizontal accuracy and the R.M.S.E. as well other criteria for different scale maps intended for use with ten common map scales.

Table 7 Different R.M.SE with Different Map Scale

Map Scale	RMS (E or N)m, ISPRS[1]	RMS (E or N)m, NMAS[2]	RMS (E or N)m, NMAS[3]
1:1000	0.25	0.30	0.50
1:2500	0.625	0.75	1.25
1:5000	1.25	1.50	2.50
1:10,000	2.50	3.00	5.00
1:15,000	3.75	4.50	7.50
1:20,000	5.00	6.00	10.00

Table 8. Horizontal Accuracy R.M.S$_E$ and Map Scale

Map Scale	Approximate Source Imagery GSD	Horizontal Data Accuracy Class	RMSEx or RMSEy (cm)	RMSEr (cm)
1:100	1-2 cm	I	1.3	1.8
		II	2.5	3.5
		III	3.8	5.3
1:200	2-3 cm	I	2.5	3.5
		II	5.0	7.1
		III	7.5	10.6
1:250	3-4 cm	I	3.1	4.4
		II	6.3	8.8
		III	9.4	13.3
1:500	4-10 cm	I	6.3	8.8
		II	12.5	17.7
		III	18.8	26.5
1:1,000	10-20 cm	I	12.5	17.7
		II	25.0	35.4
		III	37.5	53.0
1:2,000	20-30 cm	I	25.0	35.4
		II	50.0	70.7
		III	75.0	106.1
1:2,500	30-40 cm	I	31.3	44.2
		II	62.5	88.4
		III	93.8	132.6
1:5,000	40-100 cm	I	62.5	88.4
		II	125.0	176.8
		III	187.5	265.2
1:10,000	1-2 m	I	125.0	176.8
		II	250.0	353.6
		III	375.0	530.3
1:25,000	3-4 m	I	312.5	441.9
		II	625.0	883.9
		III	937.5	1325.8

<u>Conclusion:</u> This study exposed to one important use of remote sensing which is the production of large scale maps. It showed that SkySat imagery shows good potential as a source of data within a national mapping agency. The result of geometric accuracy found to be the $\sigma\Delta E$= 0.9663m and $\sigma\Delta N$ =1.0940m the total R.M.S.E = 1.459 m. are compatible with(ASPRS) standards. It was demonstrated that imagery of this type can be used for several different purposes, and this multiple use makes the imagery data considered as a practicable tool in this context. When judged against another remote sensing imagery, the SkySat images have obvious advantage of satellite imagery for its relatively high resolution (80cm, compared with others). And the advantages of frequent re-visit opportunities, rapid post-processing, large area coverage and freedom of access to remote and restricted areas. To convince large organization to modify its working practices, further studies and researches would be needed to determine whether the benefits of SkySat satellite imagery can stand up to a fully-costed business case. It is worth mentioned here that SkySat high resolution satellite imagery presents the following advantages.

- The satellite is operational 365 days of the year,
- No extra spending is incurred cost in traing more than one capture,
- The satellite orbit enables frequent re-visit times (every day) and it can deliver the production within few hours
- Imagery is post-processed relatively quickly
- No Air Traffic Control limitation apply,
- The image has a large area footprint (15X 8kmsq), cutting down the need for block adjustment and the creation of image mosaics,
- The satellite can easily access remote or restricted areas and considered using as a source of data for production large scale map with respect to international standards.
- No cameras, no aircraft or other expensive devices, equipment's are needed
- There is a strong possibility in moderate regions, that completely cloud-free images will be available, because they are pre-processed to remove the effect of clould before delivering
- The typical off-nadir viewing angle of within 15° is acceptable in a dense urban area – The geometric correction uses fine Digital Elevation Models (DEMs) with a post interval of between30 and 90 meters. where the DTM is perfect,
- The production processes required for high resolution SkySat satellite imagery are not different to those of traditional photogrammetric or another satellite data capture – no extra equipment, different production flowlines and easy training may be required,
- The reliability of capture and delivery of imagery are according the request order and within one day, the cost is 100$ per 1km^2 which acceptable comparing with others is.
- The image resolution is high when compared to large scale aerial photography and other satellite imagers.

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