JRC Scientific and Technical Reports

Orthorectification Tests Continued... Formosat-2

[Orthorectification *O*f Formosat-2 Data for use in The Common Agricultural Policy Control with Remote Sensing Programme]

Vassil Vassilev, Stefana Popova - Remote Sensing Application Center – ReSAC

Alexandra Garnier, Céline Arzel – SPOTImage

Torbjörn Westin - Spacemetric AB

Pär-Johan Åstrand, Mihaela Fotin, Pavel Milenov - EC - Services, Agriculture Unit

EUR 23400 EN - 2008

JRC EUROPEAN COMMISSION

Institute for the Protection and Security of the Citizen

The Institute for the Protection and Security of the Citizen provides research-based, systems-oriented support to EU policies so as to protect the citizen against economic and technological risk. The Institute maintains and develops its expertise and networks in information, communication, space and engineering technologies in support of its mission. The strong cross-fertilisation between its nuclear and non-nuclear activities strengthens the expertise it can bring to the benefit of customers in both domains.

European Commission
Joint Research Centre
Institute for the Protection and Security of the Citizen

Contact information
Address: Pär-Johan Åstrand
E-mail: par-johan.astrand@jrc.it
Tel.: +39-0332-786215
Fax: +39-0332-786369

http://ipsc.jrc.ec.europa.eu/
http://www.jrc.ec.europa.eu/

JRC 45688

EUR 23400 EN
ISSN 1018-5593

Luxembourg: Office for Official Publications of the European Communities

Printed in Italy

ORTHORECTIFICATION TESTS CONTINUED...
FORMOSAT-2

[ORTHORECTIFICATION OF FORMOSAT-2 DATA FOR USE IN THE COMMON AGRICULTURAL POLICY CONTROL WITH REMOTE SENSING PROGRAMME]

JRC IPSC/G03/C/PAR/ D(2008)(9233 V 1.1)

ReSAC
Vassil Vassilev, Stefana Popova
Remote Sensing Application Center - ReSAC
61, Tzar Assen Str., 1463 Sofia, Bulgaria
http://www.resac-bg.org/, resac@techno-link.com

SPOTImage
Alexandra Garnier, Céline Arzel
Spot Image, 5 rue des satellites, BP 14359, F-31030 Toulouse Cedex 4
http://www.spotimage.fr
alexandra.garnier@spotimage.fr, Celine.Arzel@spotimage.fr

Spacemetric AB
Torbjörn Westin
Tingsv. 19, SE-19161 Sollentuna, Sweden
http://www.spacemetric.com, tw@spacemetric.com

EC - Services, Agriculture Unit
Pär-Johan Åstrand, Mihaela Fotin, Pavel Milenov
[a] European Commission DG-JRC, IPSC, Agriculture Unit, TP266, I-21020 Ispra (VA), Italy
http://mars.jrc.it, par-johan.astrand@jrc.it, mihaela.fotin@jrc.it, pavel.milenov@jrc.it

KEY WORDS: Common Agricultural Policy (CAP), Control with Remote Sensing (CwRS), FORMOSAT-2 (F2), Very High Resolution (VHR), revisit capacity, off-nadir angle, orthorectification, location accuracy, rigorous modelling, accuracy, Ground Control Point (GCP), Independent Check Points (ICP), Quality Control (QC).

ABSTRACT

FORMOSAT-2 (NSPO, Taiwan) was launched on 21st of May, 2004. FORMOSAT-2 was programmed as Very High Resolution backup sensor in the CwRS campaign for the first time in 2006 [Ref 1]. Acquisition success rate has been high since it was introduced due to its high (daily) revisit capacity, but difficulties were initially encountered to reach the required location accuracy in production of orthorectified imagery. This resulted in a 1st study (2006) where FORMOSAT-2 imagery over Sofia (BG) was assessed; 4 software suites were tested on this image with low off-nadir viewing angle [Ref 2]. Results were promising, demonstrating that it is possible to perform good orthorectification using standard software packages reaching results inside the CwRS requirements for such imagery (location accuracy preliminary set to 3.5m $RMSE_{1D}$). In this 2nd study (2007) the aim has been to assess the effect of large off-nadir angles on the accuracy of the orthorectification, and to define the optimal number of GCPs to be used when orthorectifying FORMOSAT-2 images on a routine basis. Results of orthocorrection of 4 images of different off-nadir angles (along/across angles), over 2 sites in France and Bulgaria, using 4 different sw suites (PCI, ERDAS Imagine, PRODIGEO, and Keystone SIPOrtho,) and with varying number of GCPs are discussed. The results are consistent with theoretical expectations; x error increases when across angle (roll) increases, the y error increases when along angle (pitch) increases. Basically the accuracy of 5m $RMSE_{1D}$ is reached with all tested softwares, the 3.5m $RMSE_{1D}$ accuracy may be reached if limits are placed on the acquisition angles. Concerning the GCP requirement a total of minimum 10 GCPs should be used: four GCPs spread in the corners of the scenes, the others evenly distributed, and clearly visible.

1. INTRODUCTION

1.1 Study aim

The European Commission Services use remotely sensed data in a series of programmes; one of the largest being within the CAP, Control with Remote Sensing, where the aim is to identify irregularities in subsidy claims. Taking into account the enlargement of EU to 27 Member States and subsequent increased number of sites to be controlled with use of satellite imagery, the possibility to include new sensors like FORMOSAT-2 have to be explored. This will increase total acquisition capacity and will ensure timely delivery of the necessary imagery to the MS administrations and their contractors. Due to its fixed orbit FORMOSAT-2 is particularly interesting for the areas covered by its swath because of the daily revisit capacity. In this respect, the satellite is suitable to be used as backup to the "prime" dedicated VHR sensors Ikonos and Quickbird. In 2006 7.500 km^2 at 88% success rate was acquired by FORMOSAT-2, and in 2007 13.000 km^2 at 97% success rate.

The study objectives were:

- assess the effect of large off-nadir angles on the accuracy of the orthorectification
- to define the optimal number of GCPs to be used when orthorectifying FORMOSAT-2 images on a routine basis
- continue test of different sw suites

This study was performed in collaboration between ReSAC, SPOTImage, Spacemetric, and the EC Services at JRC.

1.2 Study sites

The two sites selected for the study were Sozopol (BG), site "C" (Fig. 1) and Mausanne (FR) (Fig. 2). The choice was based on the geographic location, giving the technical acquisition possibility to test different view angles (across-track), and on the available reference data of a quality enough to provide reliable results.

The Sozopol site is located in South-Eastern Bulgaria at the Black Sea coast. The landscape is hilly with some footsteps of the Strandja Mountain in the southern part of the area (elevation up to 375 meters above sea level). The land cover is equally represented by agriculture area, around the scattered settlements and forest massifs on the hills. There are very few inland water bodies. Up to 10% of the area of interest is covered by the sea.

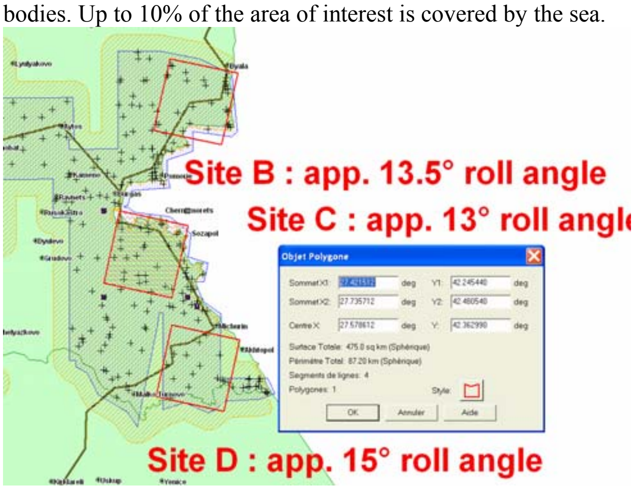


Fig. 1 - Location of Sozopol site. The available DGPS points are shown with crosses. Site "C" chosen for the study

The Mausanne site is located near to Mausanne-les-Alpilles in France. It has been used as test site by the European Commission Joint Research Centre since 1997 (Spruyt and Kay, 2004, Ref. 10). It therefore comprises a time series of reference data (DEMs, imagery, ground control) and presents a variety of agricultural conditions typical for the EU. The study site contains a low mountain massif (elevation up to around 650m above sea level), mostly covered by forest, surrounded by low lying agricultural plains. A number of small urban settlements of low density and a few limited water bodies are present in the image.

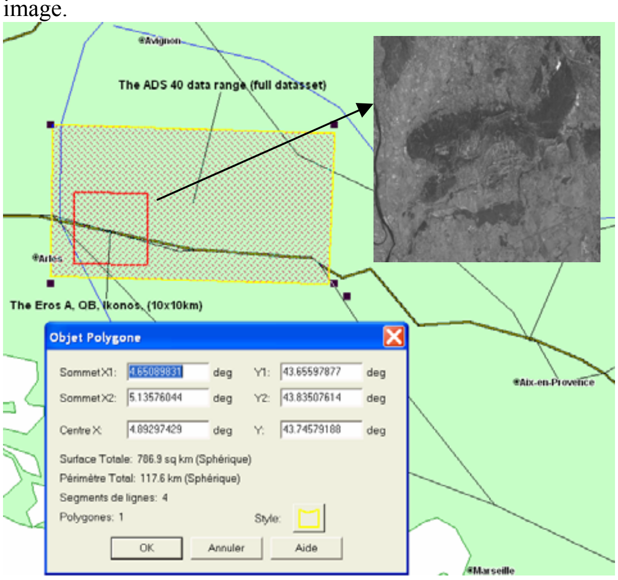


Fig. 2 - Location of the Mausanne site (FR) showing source image

1.3 Study Instrument

FORMOSAT-2 (NSPO, Taiwan) was launched on 21st of May, 2004. It carries two cameras that deliver imagery of the Earth in the visible (panchromatic (PAN), 0.45 – 0.9μm) and near infrared (multispectral (MSP), 4 bands) electromagnetic spectrum. The swath covered by these high resolution cameras is 24 km at Nadir and their nominal instantaneous geometric field of view, at Nadir, is 2 metres for the PAN sensor and 8 metres for the MSP sensor (Fig. 3). FORMOSAT-2 has a sun and geosynchronous orbit of 14 fixed orbits/day and the sensor can be tilted ± 45° along and across track which results in a daily revisit time within the corridor covered (Fig. 4).

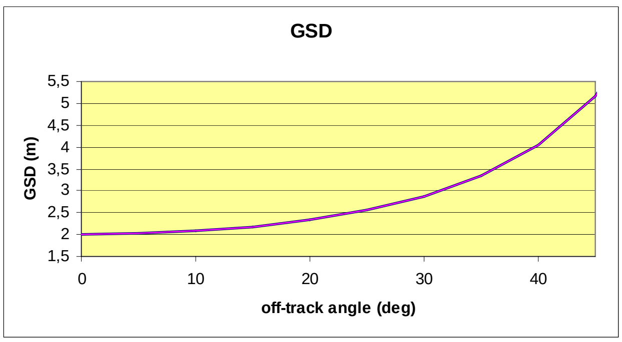


Fig. 3 - GSD at, at Nadir, is 2m PAN, and 8m MSP (off-nadir angles in all JRC studies performed cause cross track GSD(X) resolution to vary between 2.025 - 3.104m

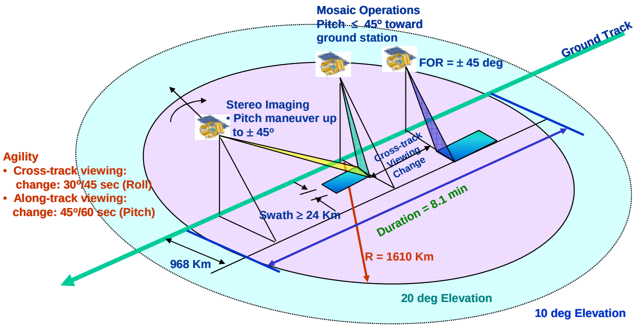


Fig. 4 - FORMOSAT-2 NSPO Taiwan; agility

1.4 Acquired Imagery

For the present study the FORMOSAT-2 imagery with the highest spatial resolution was considered, i.e. the panchromatic one, as it requires greater accuracy for the orthorectification. The radiometric resolution of this band is 8-bit.
The imagery was delivered as raw imagery, Level 1A, with basic radiometric normalisation for detector's calibration, but with no geometric correction. The product was in DIMAP format and as such comprises a GeoTIFF file for storing the imagery and an XML file – METADATA.DIM ancillary data (filtered ephemeris and attitude data, refined focal plane calibration). Further details on the 4 images acquired are given in Table 1 below.

Site - date	Along track angle	Across track angle	GSD (X)
SOZ 1 - 04/04/07	-0.692732°	17.687877°	2.680
SOZ 2 - 26/04/07	29.878595°	17.762129°	3.104

Site	Along track angle	Across track angle	GSD (X)
MAUS 1 - 21/03/07	-15.9666662°	+26,822819°	2.340
MAUS 2 - 25/03/07	-30.893181°	+26,246151°	2.803

Table 1 - Characteristics of the four FORMOSAT-2 images used in the study

2. METHODS

2.1 Software

Given that the objective of the study was to determine whether FORMOSAT-2 imagery could be used by contractors orthocorrecting imagery on a routine basis for farmers' subsidies monitoring the main internationally recognised software platforms were firstly considered. Specifically, for this study, PCI Geomatica 10 and ERDAS Imagine 9.1 were tested for orthorectification performance. In addition, the orthorectification was performed with some image provider/vendor specific software suites: PRODIGEO of EADS SPOTImage and Keystone SIPOrtho of Spacemetric.

2.2 Reference Data

Ground reference data for the Sozopol site included:

- 29 GCPs/CPs from previous very accurate DGPS measurements ($RSME_{2D}$ and RMSEz of < 0.05 m)
- DEM from SPOT Reference3D with RMSEz of < 3.5 m [Ref. 2, 8].
- IK orthoimages, produced with the above mentioned DEM and GCPs with $RMSE_{2D}$ of the different tiles (based on independent CPs) from 0.7m to 1.82 m.

Ground reference data for the Mausanne site included:

- 53 GCP/CP from DGPS measurements with accuracy of (x, y) < 0.05m and (z) < 0.1 m
- Orthophotos from aerial flight using ADS40 (RMSEx = 0.88 m and RMSEy = 0.72 m)
- DEM from SPOT Reference3D
- DEM generated from ADS40 (GSD=2.0 m), with RMSEz of 0.6 m (compared to the Z-value of the independent well-defined points)

According to the JRC guidelines [Ref 3], the RMSE of the GCPs used in orthorectification should be 3 times better than the tolerable RMSE. This was set preliminary to 3.5m for FORMOSAT-2 at low/moderate off-nadir viewing [Ref 2]. For the purpose of this Study the use of well distributed GCPs from the reference orthophotos (Ikonos orthoimages for Sozopol, and the orthophotos from the aerial flight using ADS40 for Mausanne) were judged adequate for the orthorectification. This also fits with the most commonly used, and afforded, reference data by the contractors during the CwRS campaign. The CwRS contractors in fact most often use the national orthophoto coverage (with accuracy of 0.5 m to 1.5 m) to collect GCPs for the orthorectification of VHR data. Another reason to use GCPs from the orthophoto is that this allowed more flexibility in the selection of the control points, than to rely on limited set of DGPS point, which might not be well visible and/or properly distributed.

The DGPS points mentioned above were solely used as ICPs for the external QC.

The DEM used in this study was the first layer of the product of SPOT Image – Reference3D – produced from SPOT-5's HRS stereo pairs. The absolute elevation accuracy of the Reference3D product is 10 metres with @ confidence of 90% for a slope less then 20 degrees, while the planimetric accuracy is as good as 15 metres. Testing the Ref3D accuracy over Sozopol cf. DGPS points gave an accuracy of 3.440m RMSEz. Earlier tests over Sofia, BG [Ref 2] gave accuracy values of down to 2.968m RMSEz. It was concluded that the Ref3D is suitable for orthorectification of the FORMOSAT-2 satellite imagery.

2.3 Orthorectification and Quality Control

The four FORMOSAT-2 images were orthorectified with PCI Geomatica, ERDAS Imagine, PRODIGEO and Keystone SIPOrtho.
In order to ensure the consistency of the software performance test, all GCPs and ICPs were identically chosen for each software-respective test, and their image and ground coordinates were transferred via import, to avoid errors during the tests. The number and location of the ground control points were in accordance with the "Guidelines for Best Practice and Quality Checking of Ortho Imagery" [Ref 3]. For the purpose of the GCPs, 15 well identified points were selected from the

reference orthophotos. Imagettes with the position of the point on the raw data was also extracted.
In order to have comparable results the DEM used for the test was the Reference3D product by Spot Image.
It is clear that having a strict control on the reference data and a sufficient proven quality, the results of the orthorectification will be mainly influenced by the accuracy of the geometrical model and not by external factors.
Orthorectification was performed in stepwise series using 6-15 GCPs (PCI 32 orthorectifications, ERDAS Imagine 40, PRODIGEO 20, and Keystone SIPOrtho 40; ∑ 132 orthorectifications)
The geometric assessment that was undertaken afterwards was systematic and conforms to the standard method developed by the JRC in the “Guidelines for Best Practice and Quality Checking of Ortho Imagery” [Ref 3]. This method applies strict use of points other, and more accurate, than the ones used in the orthorectification, i.e. ICPs, for the evaluation of image correction performance, which allows the comparative robustness between different processing methods. DGPS points (see Section 2.2 Reference Data) of cm accuracy were used for this purpose: 15 over Sozopol and 20 over Mausanne. Geometric assessment was performed by viewing imagettes, thereafter placement, and measurement of the DGPS points on the orthophoto to be checked. Orthophotography corrected with 8, 10, 12, 15 GCPs were checked: residuals and RMSE calculated on a total of 64 images.

Fig 5 - Imagette and photo used in geometric assessment

3. ORTHORECTIFICATION PROCESS

3.1 Orthorectification with PCI

The PCI sw suite has a dedicated FORMOSAT-2 rigorous physical model (Toutin, 2004 [Ref 6]) available upon loading the original GeoTIFF image file (patch 10031 was used which includes critical enhancements made for the F2 modelling). The application reads image metadata supplied in the DIMAP format. PCI requires an extra step prior to the input of GCPs for refinement of the exterior orientation, which involves reading the raw satellite data and its transformation into a file with the PIX wildcard – the software's internal file format. A minimum of 8 points are necessary to solve the model why only 32 orthocorrections could be performed making use of 8, 9, 10, 11, 12, 13, 14, 15 GCPs on each of the 4 images on hand (∑32 orthocorrections). The model adjustment residuals and RMSE were calculated.
The quality of the PCI modelling appears primarily dictated by the quality and the good distribution of the GCPs. The convergence of the model is more sensitive to no. of GCPs cf. to PRODIGEO and Keystone SIPOrtho. The model performs well independent of off-nadir viewing angles, when GCPs are sufficient [Table 2-5, Fig 5-8]

3.2 Orthorectification with ERDAS IMAGINE

The ERDAS Imagine sw suite applies the orbital pushbroom model (patch 32472 was used that adds a geometric modelling for FORMOSAT-2). Also ERDAS Imagine reads ephemeris data directly from the DIMAP format. Orthocorrections were performed using 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 GCPs on each of the 4 images on hand (∑40 orthocorrections). The model adjustment residuals and RMSE were calculated. Also for ERDAS, the quality of the modelling appears primarily dictated by the quality and the good distribution of the GCPs. The convergence of the model is more sensitive to no. of GCPs cf. to PRODIGEO and Keystone SIPOrtho. The model result is strongly influenced by large along track angle (pitch) and there is a need to model the along angle (y component) properly[1]. The model is less sensitive to large across track angle (roll) [Table 2-5, Fig 5-8]

3.3 Orthorectification with PRODIGEO, and Keystone SIPOrtho

Both sw suites use a rigorous physical model based on orbit and attitude parameters (independent of the ground). The quality of the modelling is primarily dictated by the rigorous restitution of the position/orientation of the satellite via the auxiliary data. The number of parameters to be adjusted can be varied. The default Formosat adjustment uses 6 parameters. There is always a trade-off between model accuracy and stability; using few parameters in the model will give stable results with few GCPs, using larger numbers of parameters will give possibility for a more accurate model but will then require larger numbers of GCPs to give reliable results.
As for PCI, and ERDAS Imagine these applications both read image metadata supplied in the DIMAP format. Orthocorrections were performed using 6, 8, 10, 12, 15 GCPs on each of the 4 images on hand for PRODIGEO (∑20 orthocorrections). Orthocorrections were performed using 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 GCPs on each of the 4 images on hand for Keystone SIPOrtho (∑40 orthocorrections). The model adjustment residuals and RMSE were calculated.
Both perform well at high off-nadir viewing angles (especially for high along track angle (pitch)). In Keystone SIPOrtho the along track component is modeled by a 3^{rd} degree variation in along track angle (pitch) by addition of 3 additional parameters. In both the convergence of the model is less sensitive to no. of GCP cf. with PCI and ERDAS Imagine [Table 2-5, Fig 5-8]

[1] New fix 33599 for ERDAS Imagine 9.1 including improved F2 support appears to solve the along angle modelling problem [Ref 9].

Site	GCPs used	SW suite used	external QC JRC (on ICPs)		
	GCPs used		rmseX	rmseY	2D meters
MAUS 1	8	PCI	6,6665	15,6898	17,0474
MAUS 1	8	ERDAS	4,2869	4,6683	6,3380
MAUS 1	8	SipOrtho/Keystone	3,5560	2,4164	4,2993
MAUS 1	8	PRODIGEO	4,5296	2,7541	5,3012
MAUS 1	10	PCI	4,6603	3,3992	5,7682
MAUS 1	10	ERDAS	3,8546	2,6672	4,6874
MAUS 1	10	SipOrtho/Keystone	3,5669	2,2494	4,2169
MAUS 1	10	PRODIGEO	5,1090	2,7452	5,7998
MAUS 1	12	PCI	4,3317	3,2294	5,4030
MAUS 1	12	ERDAS	4,0359	2,8509	4,9413
MAUS 1	12	SipOrtho/Keystone	3,7948	2,2086	4,3907
MAUS 1	12	PRODIGEO	5,0127	3,3237	6,0145
MAUS 1	15	PCI	4,1804	3,0358	5,1664
MAUS 1	15	ERDAS	3,5340	2,6837	4,4375
MAUS 1	15	SipOrtho/Keystone	3,7508	2,2727	4,3857
MAUS 1	15	PRODIGEO	4,7812	2,9986	5,6437

Table 2 - External QC of the MAUS 1 image

Site	GCPs used	SW suite used	external QC JRC (on ICPs)		
	GCPs used		rmseX	rmseY	2D meters
MAUS 2	8	PCI	6,6771	16,1125	17,4412
MAUS 2	8	ERDAS	11,2026	31,2716	33,2177
MAUS 2	8	SipOrtho/Keystone	3,8260	2,8573	4,7752
MAUS 2	8	PRODIGEO	4,6204	4,0881	6,1694
MAUS 2	10	PCI	3,7505	4,1394	5,5858
MAUS 2	10	ERDAS	23,3090	53,5554	58,4079
MAUS 2	10	SipOrtho/Keystone	3,2621	2,9424	4,3931
MAUS 2	10	PRODIGEO	4,9578	3,9254	6,3237
MAUS 2	12	PCI	3,8237	4,0931	5,6013
MAUS 2	12	ERDAS	14,5497	21,8033	26,2121
MAUS 2	12	SipOrtho/Keystone	3,5006	3,1597	4,7157
MAUS 2	12	PRODIGEO	5,0793	3,8041	6,3459
MAUS 2	15	PCI	4,1210	3,9058	5,6778
MAUS 2	15	ERDAS	13,3278	18,9219	23,1445
MAUS 2	15	SipOrtho/Keystone	4,0194	3,1278	5,0930
MAUS 2	15	PRODIGEO	5,4263	4,2312	6,8810

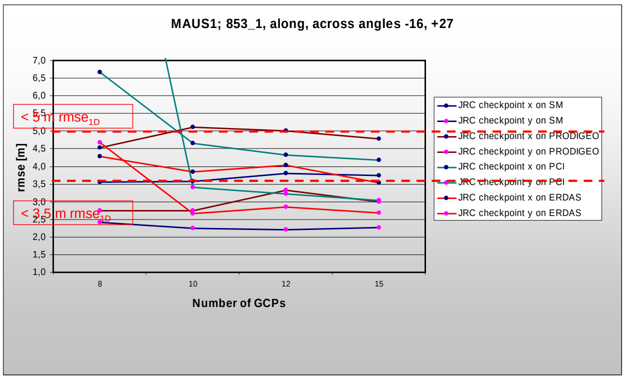
Table 3 - External QC of the MAUS 2 image

Site	GCPs used	SW suite used	external QC JRC (on ICPs)		
	GCPs used		rmseX	rmseY	2D meters
SOZ 1	8	PCI	3,7400	1,9567	4,2209
SOZ 1	8	ERDAS	2,8176	5,2089	5,9221
SOZ 1	8	SipOrtho/Keystone	2,1074	2,4070	3,1992
SOZ 1	8	PRODIGEO	2,2370	2,3349	3,2335
SOZ 1	10	PCI	2,5613	2,1698	3,3568
SOZ 1	10	ERDAS	2,3602	2,5288	3,4591
SOZ 1	10	SipOrtho/Keystone	1,7344	2,3523	2,9226
SOZ 1	10	PRODIGEO	2,1605	2,4018	3,2305
SOZ 1	12	PCI	2,4532	2,3156	3,3735
SOZ 1	12	ERDAS	2,1800	2,7610	3,5179
SOZ 1	12	SipOrtho/Keystone	1,4449	2,3279	2,7398
SOZ 1	12	PRODIGEO	2,2992	2,1342	3,1371
SOZ 1	15	PCI	2,3385	2,1400	3,1699
SOZ 1	15	ERDAS	1,9383	2,7186	3,3388
SOZ 1	15	SipOrtho/Keystone	1,7637	2,3198	2,9142
SOZ 1	15	PRODIGEO	2,5687	1,8646	3,1741

Table 4 - External QC of the SOZ 1 image

Site	GCPs used	SW suite used	external QC JRC (on ICPs)		
	GCPs used		rmseX	rmseY	2D meters
SOZ 2	8	PCI	4,6010	10,2214	11,2092
SOZ 2	8	ERDAS	12,2700	20,0675	23,5214
SOZ 2	8	SipOrtho/Keystone	1,6368	3,6863	4,0333
SOZ 2	8	PRODIGEO	2,5687	1,8646	3,1741
SOZ 2	10	PCI	2,1183	2,4402	3,2314
SOZ 2	10	ERDAS	16,1960	37,5661	40,9087
SOZ 2	10	SipOrtho/Keystone	0,9473	4,0950	4,2031
SOZ 2	10	PRODIGEO	2,4954	4,9806	5,5708
SOZ 2	12	PCI	1,6633	2,8751	3,3216
SOZ 2	12	ERDAS	11,1688	36,0725	37,7620
SOZ 2	12	SipOrtho/Keystone	1,3564	4,1841	4,3985
SOZ 2	12	PRODIGEO	2,7062	5,2619	5,9170
SOZ 2	15	PCI	1,8450	2,7970	3,3507
SOZ 2	15	ERDAS	3,7976	28,3522	28,6054
SOZ 2	15	SipOrtho/Keystone	1,3793	4,0946	4,3206
SOZ 2	15	PRODIGEO	2,7228	5,9535	6,5466

Table 5 - External QC of the SOZ 2 image



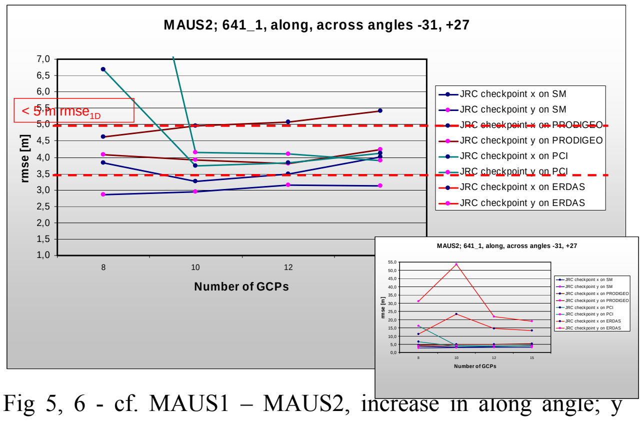
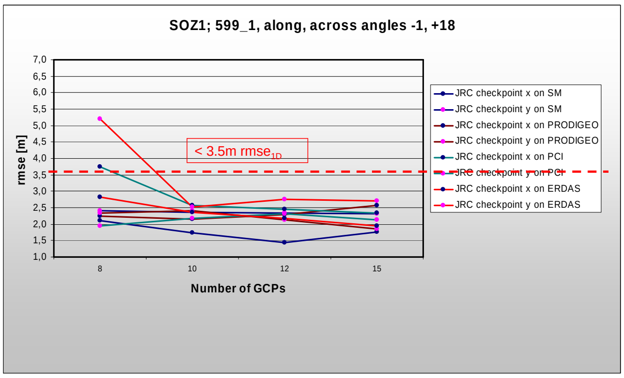


Fig 5, 6 - cf. MAUS1 – MAUS2, increase in along angle; y component error increase; large error in the ERDAS Imagine model.



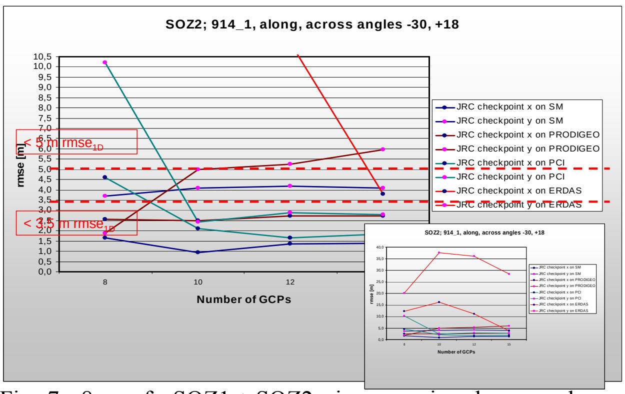


Fig 7, 8 - cf. SOZ1–>SOZ2, increase in along angle; y component error increase; large error in the ERDAS Imagine model cf. SOZ ->MAUS x-component error increase (across track)

3.4 Orthorectification Summary

It was demonstrated that it was possible to perform good orthorectification using the software packages tested. The accuracy of 5m $RMSE_{1D}$ is reached with all tested softwares, at all off-nadir view angles, except ERDAS that should be corrected to model the along angle properly[1][Ref 9] 3.5m $RMSE_{1D}$ accuracy may be reached if limits are placed on the acquisition angles. Extrapolating the results of these tests, it is suggested that these limits are placed at a maximum of 20 deg for across track angle, and at a maximum of 25 deg for along track angle.

4. CONCLUSIONS

Following the 1st study (2006, Ref 2) where FORMOSAT-2 imagery of low/moderate off-nadir viewing was assessed giving orthorectification results within the CAP CwRS accuracy threshold for this type of imagery (preliminary set to 3.5 $RMSE_{1D}$), this 2nd study (2007) further assesses the effect of large view angles on orthorectification accuracy, and defines the optimal number of GCPs to be used when orthorectifying FORMOSAT-2 images on a routine basis for the purpose of the CAP Control with Remote Sensing programme. Four FORMOSAT-2 images over two sites (France and Bulgaria) were used in the study. Four different sw suites (PCI Geomatica, ERDAS Imagine, PRODIGEO and Keystone SIPOrtho) were used in the orthorectification tests which were performed systematically and under strict control with varying no. of GCPs. Results were quality assessed in line with the JRC "Guidelines for Best Practice and Quality Checking of Ortho Imagery" [Ref 3]. In total 132 orthorectifications were performed using 6-15 GCPs and thereafter geometric assessment was made on 64 of these orthophotos.

The following important overall conclusions may be drawn after the study:

The effect of the acquisition angles on one dimensional errors is consistent with theoretical expectations; x error increases when across angle (roll) increases, i.e. from image SOZ to MAUS, while the y error increases when along angle (pitch) increases (satellite viewing direction) i.e. from image SOZ1 to SOZ2, and MAUS1 to MAUS2.

Basically the accuracy of 5m $RMSE_{1D}$ is reached with all tested softwares, except ERDAS that should be corrected to model the along angle properly. Vassilev [Ref 9] reported that with the new fix of ERDAS (fix 33599), issued by Leica Geosystems in June 2007, the FORMOSAT model was significantly improved[1]. 3.5m $RMSE_{1D}$ accuracy may be reached if limits are placed on the acquisition angles. Extrapolating the results of the tests performed, it is suggested using maximum 20 deg for across track angle, and 25 deg for along track angle. This is consistent with GSD as a function of satellite viewing angles. GSD remains below 2.5m if above angles are maintained, and F2 may therefore be used for a similar purpose as SPOT supermode as far as the PAN image content concerns.

Concerning the GCP requirement a total of minimum 10 GCPs should be used: four GCPs spread in the corners of the scenes, the others evenly distributed, and clearly visible. Moreover the use of GCPs from a reference dataset (e.g. aerial orthophoto or satellite orthoimage) already available in the EU Member States and broadly used for the LPIS is possible.

Concerning DEM the Ref3D (grid size 25m, $RMSEz < 3.5m$) appears appropriate.

At last, since the PAN and the MSP bands of the FORMOSAT-2 sensor are not registered simultaneously further tests should be made on orthorectification of the MSP bands, and on the result of pansharpening, for the use of these multispectral bands within computer aided photointerpretation and crop identification relevant for CAP CwRS.

5. REFERENCES AND SELECTED BIBLIOGRAPHY

1.) *Formosat-2 performance in the CwRS Campaign 2006, and future…,* Mangolini M et al., GISCAP, Toulouse, 27-29 November 2006 [presentation available at URL: http://agrifish.jrc.it/marspac/meetings/Toulouse2006/programme.htm]

2.) Orthorectified Formosat-2 data performance in the CwRS Campaign 2006 and future applications, Vassilev V et al., [ref. JRC IPSC/G03/C/PAR/ D(2007)(7945)), JRC PUBSY 42800]

3.) *Guidelines for Best Practice and Quality Checking of Ortho Imagery* [ref. JRC IPSC/G03/P/SKA/ska D(2003)(2402)) Version 2.6 date June 2007]

4.) *Common Technical Specifications for the 2007 Campaign of Remote-Sensing Control of area-based subsidies* ITT no. 2006/S 229-244998 (01 December 2006) [ref. JRC IPSC/G03/P/HKE/hke D(2006)(6388) file://S:\FMPArchive\P\6388.doc]

5.) *VHR Imagery Specifications for the CwRS Programme* (ref. JRC IPSC/G03/C/PAR/ D(2007)(7528) file://S:\FMPArchive\C\7528.doc]

6.) Toutin, T., 2004. Review article: *Geometric processing of remote sensing images: models, algorithms and methods.* Int. J. Remote Sensing, 20 May, 2004, Vol.25, No10, 1893-1924.

7.) *Creation of Digital Orthoimage Map on the Base of VHR Satellite Images for the Bulgarian LPIS*, Vassilev V. et al, Proceedings of the 12th MARS PAC Annual Conference "Geographical Information in Support of the CAP", Toulouse, 2006

8.) Orthorectification performance of Formosat-2 with Digital Elevation Model from different sources for further utilisation in CwRS campaigns, Vassilev V., S. Popova, Poster Session of the 13th MARS PAC Annual Conference "Geographical Information in Support of the CAP", Madrid, 2007

9.) Influence of the DEM and Incidence angle on the orthorectification accuracy of Formosat-2 for the purposes of Fast Track Disaster Mapping (Vassil Vassilev, Stefana Popova) [Int. Conference of Cartography and GIS, Borovets, 21-24 January, 2008]

10.) Mausanne Test Site - European Commission Joint Research Centre 1997 (Spruyt and Kay, 2004).

European Commission

EUR 23400 EN – Joint Research Centre – Institute for the Protection and Security of the Citizen
Title: Orthorectification Tests continued… Formosat2
Author(s): Pär-Johan Åstrand, Mihaela Fotin, Pavel Milenov, Vassil Vassilev, Stefana Popova,
Alexandra Garnier, Céline Arzel, Torbjörn Westin

Luxembourg: Office for Official Publications of the European Communities
2008 – 10 pp. –21 x 29.7 cm
EUR – Scientific and Technical Research series – ISSN 1018-5593

Abstract

FORMOSAT-2 (NSPO, Taiwan) was launched on 21st of May, 2004. FORMOSAT-2 was programmed as Very High Resolution backup sensor in the CwRS campaign for the first time in 2006 [Ref 1]. Acquisition success rate has been high since it was introduced due to its high (daily) revisit capacity, but difficulties were initially encountered to reach the required location accuracy in production of orthorectified imagery. This resulted in a 1st study (2006) where FORMOSAT-2 imagery over Sofia (BG) was assessed; 4 software suites were tested on this image with low off-nadir viewing angle [Ref 2]. Results were promising, demonstrating that it is possible to perform good orthorectification using standard software packages reaching results inside the CwRS requirements for such imagery (location accuracy preliminary set to 3.5m $RMSE_{1D}$). In this 2nd study (2007) the aim has been to assess the effect of large off-nadir angles on the accuracy of the orthorectification, and to define the optimal number of GCPs to be used when orthorectifying FORMOSAT-2 images on a routine basis. Results of orthocorrection of 4 images of different off-nadir angles (along/across angles), over 2 sites in France and Bulgaria, using 4 different sw suites (PCI, ERDAS Imagine, PRODIGEO, and Keystone SIPOrtho,) and with varying number of GCPs are discussed. The results are consistent with theoretical expectations; x error increases when across angle (roll) increases, the y error increases when along angle (pitch) increases. Basically the accuracy of 5m $RMSE_{1D}$ is reached with all tested softwares, the 3.5m $RMSE_{1D}$ accuracy may be reached if limits are placed on the acquisition angles. Concerning the GCP requirement a total of minimum 10 GCPs should be used: four GCPs spread in the corners of the scenes, the others evenly distributed, and clearly visible.