ORTHORECTIFIED FORMOSAT-2 DATA PERFORMANCE IN THE CWRS CAMPAIGN 2006 AND FUTURE APPLICATIONS

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ABSTRACT

Formosat 2 (NSPO, Taiwan) was launched on 21st of May, 2004. Formost2 was programmed as Very High Resolution (VHR) backup sensor for the 2006 years CwRS Campaign over 12 control zones (7.474 km2). The area success rate was as high as 87.5% (10/12 sites). The delivery of cloud free imagery was more than acceptable (88.9% < 5%, 11.1 % < 8 % Cloud Cover). Delivery of Level 1A radiometrically corrected sites worked very smoothly with average image production time of 4 days. Difficulties were however encountered to reach the required location accuracy in production of Level 3 orthorectified imagery (3.5 $RMSE_{1D}$, [ref 1]) for the sites. A presentation at Toulouse CwRS Conference [ref 2] deals with the difficulties encountered over the control sites, which resulted in embarking on present study on the Sofia F2 imagery. This study makes robust modelling using 4 software suites on near nadir F2 imagery making use of GCPs from DGPS measurements and from orthoimagery separately allowing accordingly the examination of the effect of accuracy measurements, and the effect of point distribution on orthorectification. Results are promising demonstrating that it is possible to perform good orthorectification using standard software packages reaching results inside the CwRS requirements. Future tests should however be carried out as to define the optimal number of GCPs to be used when orthorectifying F2 images on a routine basis. Furthermore, the effect of the incidence angle on the accuracy of the orthorectification should also be studied.

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 Control with Remote Sensing where aim is to identify irregularities in subsidy claims. Taking into account the enlargement of EU to 27 Member States and subsequent increased number of the 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 the 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 could be used as backup of the “prime” dedicated VHR sensors IKONOS and Quickbird.

The study objectives were:

1. to determine a reliable, operational, approach for orthorectification of the FORMOSAT-2;

2. to perform the orthorectification with different vendor-specific and off-the-shelf image processing sw suites and to compare the results

1.2 Study site

The study area covers the extent of Sofia City - the capital of Bulgaria, - and the Northern hillsides of Vitosha Mountain. The capital is situated in Sofia Valley which is an important for the agricultural plain. The average elevation inside the city is 550m a.s.l., while the nearest highest point is Cherni Vrah ("Black Peak"), 2290m, located to the South, in the Vitosha Mountain.
The study area presents various landscapes and terrain variations, thus being a suitable test site for orthorectification and geometry quality assessment.

1.3 Study Instrument and Acquired Imagery

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. F2 has a sun and geosynchronous orbit of 14 fixed orbits/day, and the sensor can be tilted ± 45º along and across track which results in a daily revisit time within the corridor covered.

For the present study the imagery with the highest spatial resolution was considered, i.e. the panchromatic one, as it requires greater accuracy for the orthorectification result.

The image is delivered as raw imagery, Level 1A, with basic radiometric normalisation for detector's calibration, but with no geometric correction. The product is in DIMAP format and as such comprises a GeoTIFF file for storing the imagery and an XML file – enhanced METADATA.DIM ancillary data (filtered ephemeris and attitudes, refined focal plane calibration) the metadata. Other specific data are given in Table 1 below.

Instrument	FORMOSAT-2
Acquisition	
Date	006-09-08
Time	08:48:06.263983
Processing	Level 1A – system radiometric and geometric correction
Radiometric Resolution	8-bit PAN
Spatial Resolution	1200x1200 pixel 2m
Viewing Angles	
Along-track	0.245404
Across-track	-6.453257
Satellite Angles	
Incidence	7.367684
Azimuth	102.202983
Satellite Altitude	895851.71817027032 m

Table 1. General characteristics of imagery acquired for the City of Sofia test area

The location of the imagery is given on Figure 1 below.

Figure 1. Location of imagery acquired for the study site. The dark-grey rectangle with white border defines the 24km footprint of the Formosat-2 imagery.

2. METHODS

2.1 Software

Given that the objective of the study was to determine whether FORMOSAT-2 imageries could be used in operational mode for farmers' subsidies monitoring, the main internationally recognised software platforms were primarily 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 vendor specific software suites – ProdiGeo of SPOT Image and SIPOrtho of Spacemetric.

Both PCI (Toutin, 2004) and ERDAS have a dedicated FORMOSAT2 rigorous physical model, available upon loading the original GeoTIFF image file. Both applications read image metadata supplied in the DIMAP format. PCI, however, 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.

2.2 Reference Data

For refining the exterior orientation and for quality control of the ortho product 22 points measured by survey-precise Differential GPS equipment (Table 2) were utilised. They were relatively well distributed over the entire test area acquired by FORMOSAT-2 (Figure 2).

ACC_X	ACC_Y	ACC_Z	DEM_Discr
0.020	0.018	0.045	2.968

Table 2. Mean accuracy for the GCPs originating from DGPS points along with the average discrepancy of the Reference3D as compared to the DGPS data available in ReSAC's database for the study area.

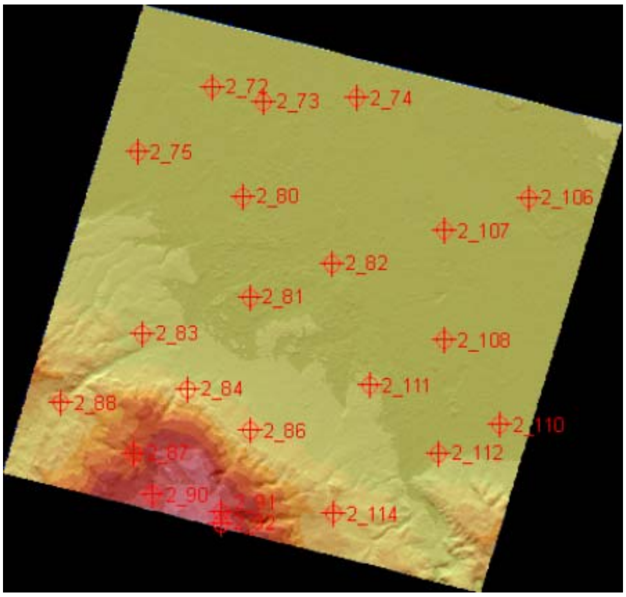

Figure 2. Distribution of the GCPs measured by DGPS system over the Reference 3D DEM clipped with the FORMOSAT-2 test scene extent.

In order to produce a refined georeferenced product trough the process of orthorectification a Digital Elevation Model (DEM) was utilised. It ascertains that the distortions caused by the terrain are removed, making the scale constant across the image regardless of the changes in elevation. The DEM used in this study was the first layer of the product of SPOT Image – Reference3D – acquired by SPOT-5's HRS instrument (Figure 3). 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. In Table 2 it is shown that Reference3D even exceeds its specifications, therefore being rather suitable for orthorectification of VHR satellite imageries.

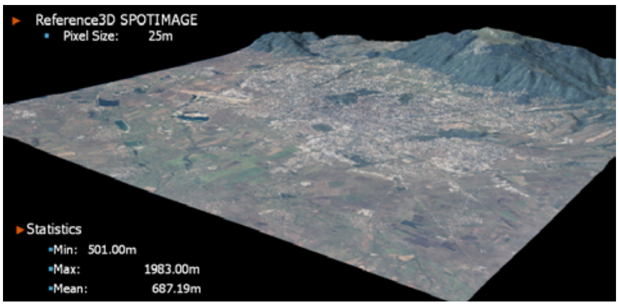

Figure 3. Overview of the terrain across the test area. For orientation IKONOS orthophoto was draped over the Reference3D DEM.

An additional test was carried out by employing GCPs and Independent Check Points (ICPs) derived from 5 IKONOS orthophotos. These images were acquired in the year-period 2003-2005, and covered the extent of the FORMOSAT test image entirely. They have a planimetric error averaging to 1.02m. The IKONOS orthophotos were chosen because they were geometrically corrected with the same GCPs as the one used in the present experiment, and therefore would assure the consistency of the results.

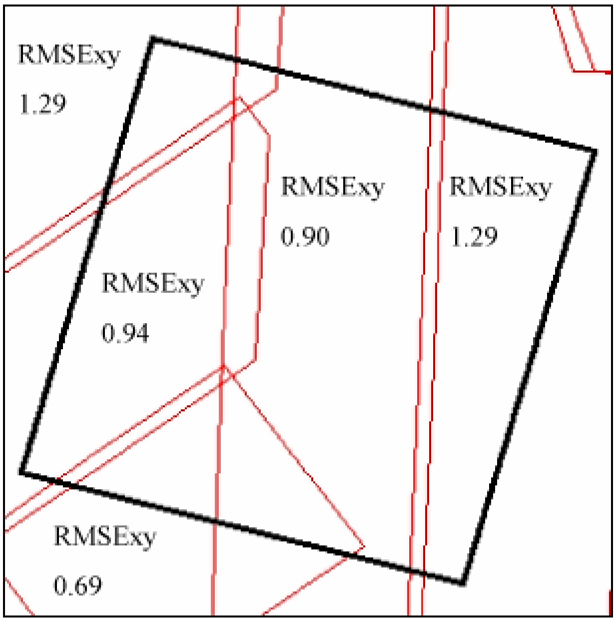

Figure 3. IKONOS ortho images' extents (red line) as opposed to the extent of the FORMOSAT test image (black bolded line). Each IKONOS orthophoto is provided along with its planimetric error.

2.3 Orthorectificaiton

The FORMOSAT-2 image was orthorectified with PCI Geomatica 10 and ERDAS Imagine 9.1, and some tests with ProdiGeo and 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 coordinates were transferred via import, to avoid interpretation errors during the tests.

In order to eliminate the influence of the DEM accuracy over the orthorectification results the best available elevation dataset over the area was chosen; in this case the Reference3D product by Spot Image. It is clear that if the reference data used is sufficient proven quality, then the results of the orthorectification will be mainly influenced by the accuracy of the geometrical model and not by external factors.

The geometric assessment that was undertaken is systematic and conforms to the standard method developed by the JRC (European Commission, 2006b). This method applies strict use of points other than the one used in the orthorectification, i.e. ICPs, for the evaluation of image correction performance, which allows the comparative robustness between different processing methods.

3. ORTHORECTIFICATION RESULTS

3.1 Geocoding by Robust Modelling

A series of tests were performed using the two main approaches – GCPs from DGPS measurements, and GCPs from IKONOS orthoimage. In the first approach the accuracy of the GCPs is very high, but the distribution is fixed and not the best for the particular scene involved in this study. On the contrary, in the second approach the best distributed GCPs were selected but their accuracy is restricted by the geometric quality of the IKONOS orthoimage. Accordingly, the first approach examines the effect of the accuracy of the measurements, while the second tests the effect of the distribution of the points on the orthorectification results.

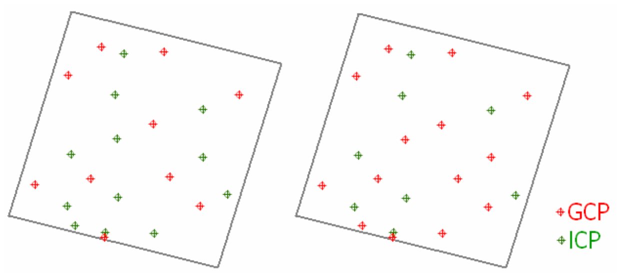

Figure 4. Distribution of Ground Control Points and Independent Check Points chosen for the orthorectification with 10 GCPs / 12 ICPs (left) and 14 GCPs / 8 ICPs (right) all measured with DGPS equipment.

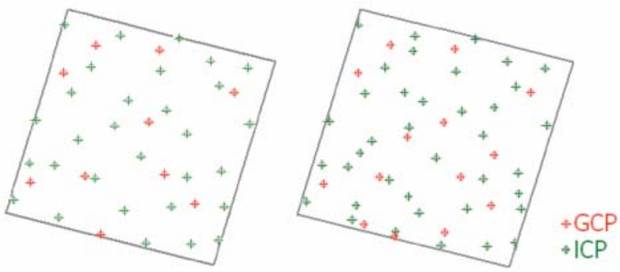

Figure 5. Distribution of Ground Control Points and Independent Check Points chosen for the orthorectification with 10 GCPs / 30 ICPs and 14 GCPs / 30 ICPs where GCPs are measured with DGPS equipment and ICPs are originating from the IKONOS reference orthoimage

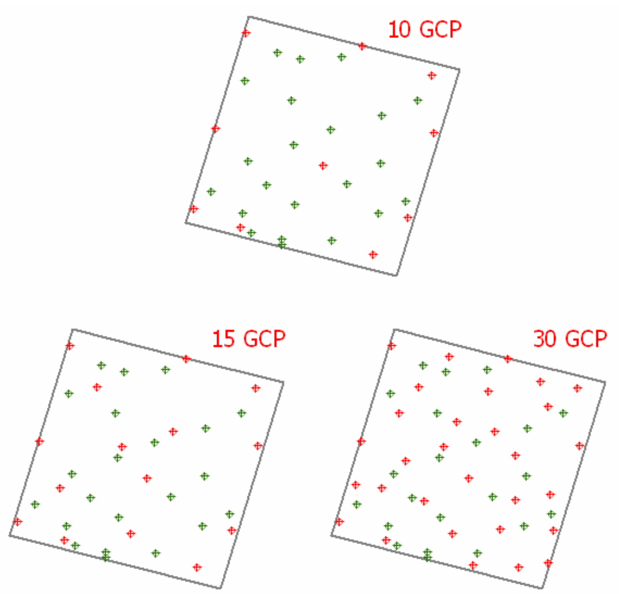

Figure 6. Distribution of Ground Control Points and Independent Check Points chosen for the orthorectification with 10 GCPs / 22 ICPs (top), 15 GCPs / 22 ICPs (left), and 30 GCPs / 22 ICPs (right). In this experiment the GCPs originate from the IKONOS reference orthoimage, and the ICPs are the measured with DGPS equipment.

Points Number and Origin	PCI	ERDAS

				Geomatica		Imagine	
GCPs	GCPs' Origin	ICPs	ICPs' Origin	RMSE X [m]	RMSE Y [m]	RMSE X [m]	RMSE Y [m]
10	DGPS	12	DGPS	4.22	2.79	2.82	4.44
14	DGPS	8	DGPS	2.7	2.79	2.17	2.47
10	DGPS	30	IKONOS	4.99	2.59	3.69	4.8
14	DGPS	30	IKONOS	3.17	2.51	2.1	2.88
10	IKONOS	22	DGPS	2.84	1.97	2.16	2.85
15	IKONOS	22	DGPS	2.35	2.33	1.84	2.21
30	IKONOS	22	DGPS	2.37	1.75	1.93	2.18

Table 4. Root Mean Square Error (RMSE) for Easting (X) and Northing (Y) directions observed for the orthorectified image in each of the software packages PCI Geomatica 10 and ERDAS Imagine 9.0.

The orthorectification with ProdiGeo and SIPOrtho and quality check of the resulting orthoimages has been performed using the points from DGPS only.

Points Number and Origin				**ProdiGeo**	
GCPs	GCPs' Origin	ICPs	ICPs' Origin	RMSE X [m]	RMSE Y [m]
10	DGPS	12	DGPS	1.832	1.5
14	DGPS	8	DGPS	1.878	1.291

Points Number and Origin				**SIPOrtho**	
GCPs	GCPs' Origin	ICPs	ICPs' Origin	RMSE X [m]	RMSE Y [m]
10	DGPS	12	DGPS	1.36	2.2
14	DGPS	8	DGPS	1.37	1.14

Table 5. Root Mean Square Error (RMSE) for Easting (X) and Northing (Y) directions observed for the orthorectified image in each of the software packages ProdiGeo and SIPOrtho.

3.2 Orthorectification Summary

It was demonstrated, that it was possible to perform good orthorectification using standard software packages. It should be mentioned that in both cases, the FORMOSAT-2 specific satellite models used were relatively new and therefore it is likely that they will improve with time.

4. CONCLUSIONS

A series of orthorectification tests were carried out in order to evaluate the operational performance of the FORMOSAT-2 sensor in the production of orthoimages, Our study shows that it was comparatively straightforward to produce reliable products, well inside the expected performance for the CwRS requirements; 3.5 $RMSE_{1D}$ (i.e. in either Northing or Easting directions).

Future research should be carried out as to define the optimal number of GCPs to be used when orthorectifying FORMOSAT-

2 images on a routine basis. Furthermore, the effect of the incidence angle (along-track, across-track) on the accuracy of the orthorectification should also be studied. These further investigations must be performed for both PCI Geomatica and ERDAS Imagine software packages, as it is likely that diverse models behave differently. Such profound analysis could aid a speedy and quality optimised orthorectification production.

5. REFERENCES AND SELECTED BIBLIOGRAPHY

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