GEOSPATIAL ASSESSMENT OF FORMOSAN-2 IMAGERY FOR SOUTHERN ARIZONA

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ABSTRACT

Launched in May 2004, Formosat-2 satellite has 8-meter resolution in multispectral and 2-meter resolution in panchromatic imagery. Its products include Level 1A with spectral correction, Level 2A with geospatial correction, and Ortho imagery productions. It had been noted from previous studies that the deficiency of ground control points (GCP) and digital elevation model (DEM) in non-Taiwan area. Using a 2-year multi-orbit orthoimagery dataset (2016) of the Wulai Mountain of the Taipei Basin, this study found that Formosat-2 imagery has excellent GCP and DEM data for the Taiwan area. However, for a non-Taiwan area, for example, Southern Arizona, United States, we have witnessed a substantial geospatial offsets ranging from 274 to 2,345 meters for its Level 2A imagery. The Formosat-2 data set of 19 images was compared to 60+ United States DOQQ (Digital Orthophoto Quarter Quad) to investigate its geospatial accuracy outside Taiwan. The Formosat-2 imagery were used to mosaic coverage of four contiguous regions. Each region was matched by a set of DOQQ imagery: Region #1 is covered by 7 DOQQ, ranging from Tinajas Atlas SW on the West to the Tule Mountains NW at the East. Regions #2 is covered by 15 DOQQ, ranging from Cabaza Priefa Peak SE at the NW, to the Las Playas NW at the SE. Region #3 is covered by 16 DOQQ, ranging from Aqua Dulce Mountains NW at the NW to West of Lukeville NE DOQQ at the SE corner. Region #4 is covered by 17 DOQQ, ranging from Tilafson Peak SW at the NW corner to Blankenship Well NE at the SE corner. After georegistration between the Formosat Regions with corresponding DOQQ imagery, geospatial accuracy assessments were performed, using reproducible control points. Region #1 has 2,235-meter offset measured between two mountain peaks – 2 images of the same object; Region #2 has 2,345-meter offset. Region #3 has 1,856-meter offset; whereas, Region #4 has 274-meters offset. This study serves as a benchmark for the geospatial accuracy of Formosat-2, as well as a potential reference for the expected Formosat-5.

KEYWORDS: Remote Sensing, Geospatial Standards, Primary Data Acquisition, Formosat-2

INTRODUCTION

Formosat-2 is the first remote sensing satellite developed by National Space Organization (NSPO), Taiwan (National Space Organization, 2016). It was successfully launched to its sun-synchronous orbit of 891 km above ground on May 21, 2004 from Vandenberg Air Force Base, CA, USA. Its main missions are to conduct remote sensing imaging over Taiwan and on terrestrial and oceanic regions of the entire earth, as well as scientific observation of natural phenomena such as lighting in the upper atmosphere (Satellite Imaging Corporation, 2017). Formosat-2 collected its last image on June 20, 2016 and was decommissioned shortly thereafter on August 1, 2016 (Apollo Mapping, 2017).

On November 5, 2007, Northwest Missouri State University (NWMSU) Geography (formerly within the Department of Geology/Geography, currently within the Department of Humanities and Social Sciences) and Formosat-2 Image Application and Distribution Center, Department of Geography, National Taiwan Normal University (NTNU FS-2) formally signed a Memorandum of Understanding (MOU) to share Formosat-2 imagery for research and teaching activities.

Formosat-2 images are unique in their spatial and temporal resolution (National Space Organization, 2016, Apollo Imaging, 2017). Multispectral Formosat-2 images contain four bands (blue, green, red and near infrared) at an eight-meter pixel size. Panchromatic Formosat-2 images contain one band at a two-meter pixel size. Therefore, applying proper pan-sharpening processes will result in a multispectral image of four bands with two-meter pixel size. With such a spatial resolution, these images are capable of monitoring heterogeneous areas, including urban

areas. Most unique is the ability to collect images daily. Because of the satellites' unique design and orbit, it is capable of collecting images of the same area every day, providing an un-paralleled capacity for monitoring rapid-change events, such as natural disasters.

Formosat-2 images of Taiwan are managed by the NSPO. To facilitate world-wide applications, Formosat-2 images of areas outside of Taiwan are available for purchase from Apollo Imaging (Apollo Imaging, 2017). Because NTNU FS-2 is a NSPO sponsored center, it has access to all Formosat-2 images, for Taiwan and worldwide. Therefore, with the MOU, Northwest can access Formosat-2 images of any location in the world, with the exception of Taiwan (due to Taiwanese security protocols).

Upon a request for student research, NTNU FS-2 delivered 19 Formosat-2 images covering southern section of Arizona, USA to NWMSU. With another request, NTNU FS-2 provided another set of Formosat-2 images covering Taipei Basin of Taiwan. Through collaboration between NWMSU and State University of New York at Binghamton, authors performed a preliminary examination on the geospatial accuracy of these imagery.

Using a 2-year multi-orbit orthoimagery dataset (2015) of the Wulai Mountain of the Taipei Basin, it was concluded that Formsat-2 imagery has excellent ground control points (gcp) and digital elevation model (DEM) data for the Taiwan area. However, for a non-Taiwan area – such as Southern Arizona, US, a substantial geospatial offset ranging from 28 – 44 to 3030 – 3110 meters against Digital Orthophoto Quarter Quadrangle (DOQQ) was observed. It had been noted from previous study (Liu, 2006) that the deficiency of ground control points (GCP) and DEM existed in non-Taiwan area; however, its magnitude of geospatial offset was not examined. This study utilized DOQQ as the reference data and examined the magnitude of geospatial offset for Formosat-2 images of non-Taiwan area.

SPATIAL ACCURACY OF FORMOSAT-2 IMAGES OF TAIPEI, TAIWAN

Google Earth Pro images were used as locational reference in assessing the spatial accuracy of Formosat-2 images of Taipei, Taiwan area. A landmark (a major dam in Wulai Mountain, Taipei Basin) was visually identified on both Formosat-2 image and Google Earth Pro, coordinates were measured on both, and compared, as shown in Figure 1. Figure 2 is a close-up of the landmark. The difference between the measured coordinates is 0 meter, meaning there is no measurable offset in spatial accuracy of Formosat-2 image in this area.

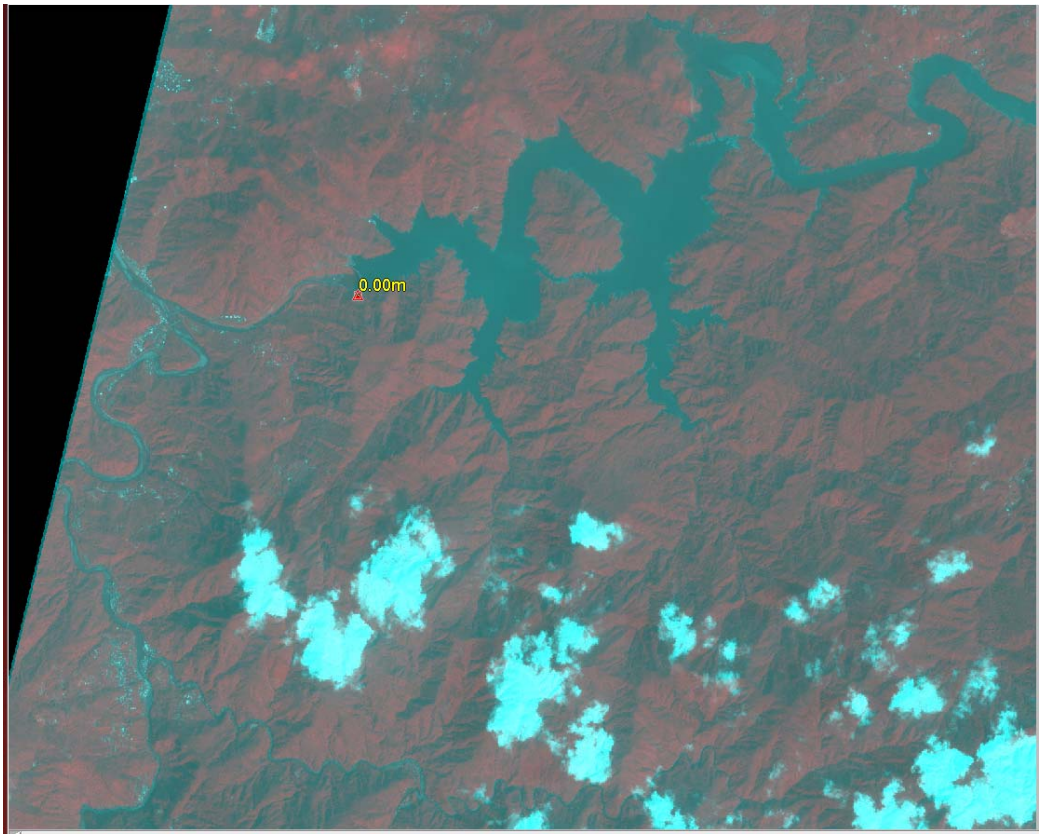

Figure 1. Landmark identified for assessing spatial accuracy of Formosat-2 image of Taipei, Taiwan.

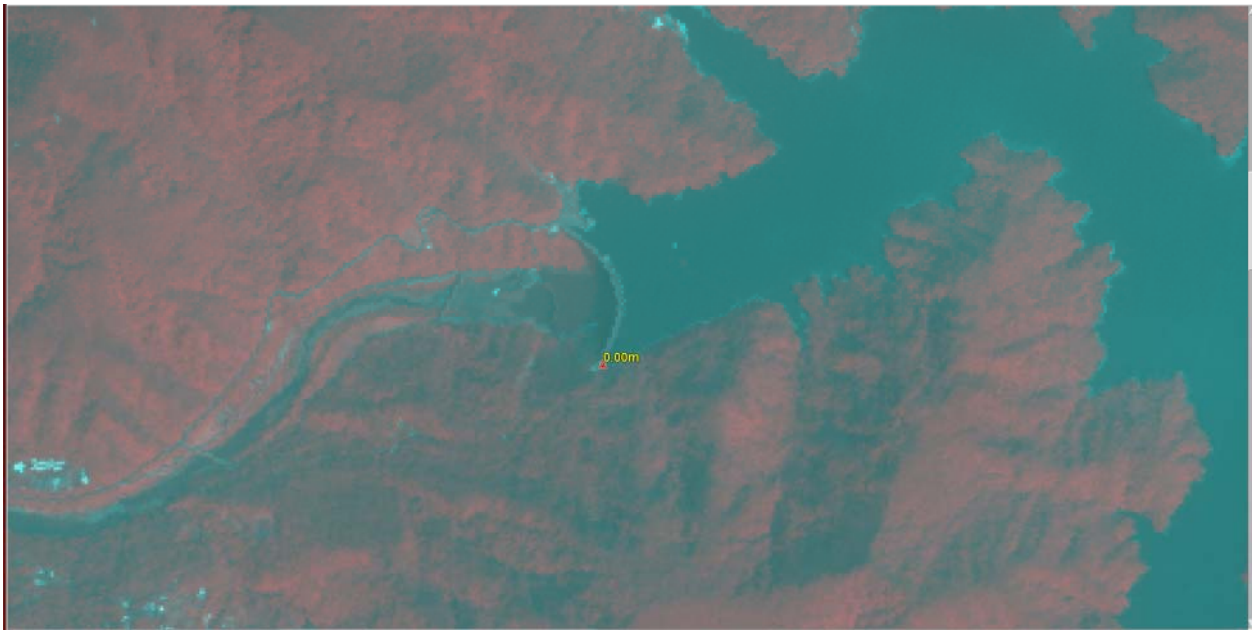

Figure 2. A close-up image of the landmark, a dam in Wulai Mountain, Taipei Basin, part of Taipei Basin Reservoir.

FORMOSAT-2 COVERAGE RELATIVE TO ARIZONA DOQQ

DOQQ is the de facto National Mapping Accuracy Standard of the United States, and is an excellent location reference for assessing the geospatial accuracy of Formosat-2 imagery outside Taiwan. The National Space Program Office (NSPO), Taiwan has done an excellent job on keeping Formosat-2 imagery at a high accuracy level as shown from scenes supplied by NSPO to authors covering a small section of the Taipei Basin (Figures 1 and 2).

Multispectral mode Formosat-2 images were mosaicked to form four contiguous regions in Arizona, USA. They were then compared to Arizona's DOQQ. More than 60 DOQQs were used to overlay these Formosat-2 images, as shown in Figure 3. Formosat-2 images were shown as gray tone images, while DOQQs were outlined in red boxes. Further examination on spatial accuracy of Formosat-2 images in Arizona was then visually inspected based on measurements from these overlay display. Table 1 summarizes location offset between DOQQs and 4 mosaicked Formosat-2 images. As one may see, the smallest offset is 28 meters, while the largest offset is 3110 meters.

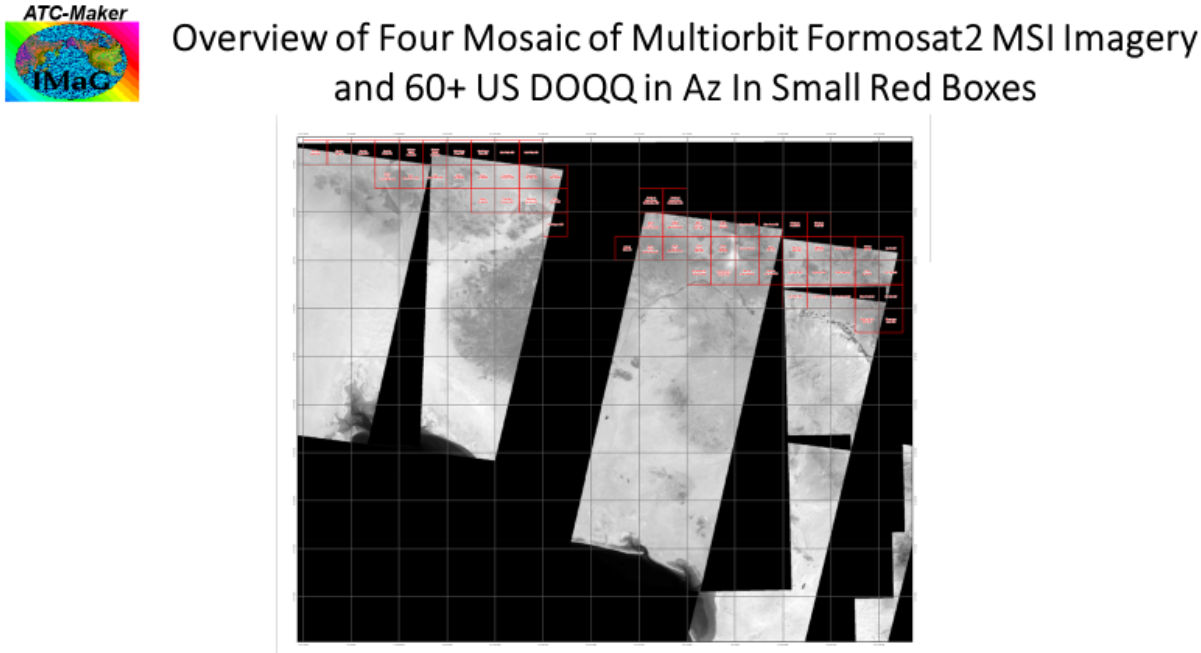

Figure 3. Coverage for Formosat-2 images and DOQQs. Formosat-2 images were gray tone images. Red boxes outline DOQQ boundaries.

Table 1. Summary of locational offset for each mosaicked Formosat-2, compared to DOQQs.

Formosat-2	# of DOQQs	# of Landmarks	Offset range
Mosaic #1	7	5	2246-2,401m
Mosaic #2	16	6	3030-3,110m
Mosaic #3	16	6	1802-1,948m
Mosaic #4	17	8	28-44m

SPATIAL ACCURACY OF FORMOSAT-2 IMAGES IN ARIZONA BASED ON DOQQ

Each mosaicked Formosat-2 image was compared to DOQQs based on coordinates. Landmarks were visually inspected and coordinates measured from both Formosat-2 and DOQQs. Several landmarks were identified within each mosaicked Formost-2 site. The column "# of landmarks" in table 1 summarizes how many landmarks were identified within each mosaicked Formosat-2 image. The following sections detail each mosaic site and their measurements.

Mosaic #1

Figure 4 shows a portion of the Formoast-2 mosaic #1 image and DOQQs. An identifiable landmark (a mountain peak in this case) was visually identified. Coordinates were measured from both mosaicked Formosat-2 images and DOQQs, as shown in figure 5. The difference between measured coordinates is 2297 meters.

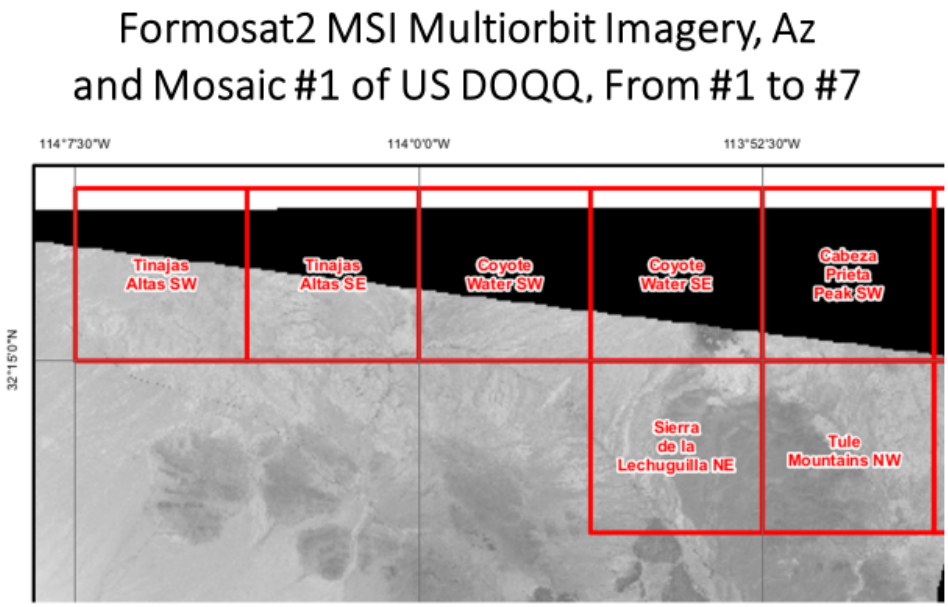

Figure 4. A portion of Formosat-2 mosaic #1 and corresponding DOQQs.

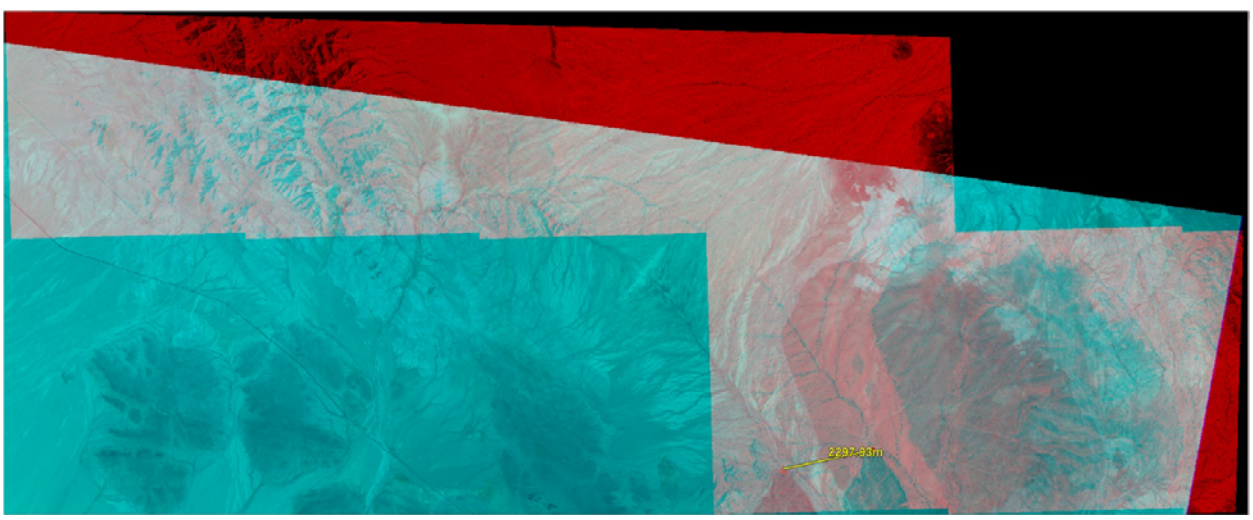

Figure 5. Comparison of a mountain peak from Formosat-2 mosaic #1 and DOQQs. The measured spatial offset between these two mountain peaks is 2297 m.

Mosaic #2

Figure 6 shows a portion of the Formoast-2 mosaic #2 image and DOQQs. An identifiable landmark was visually identified. Coordinates were measured from both mosaicked Formosat-2 images and DOQQs, as shown in figure 7. The difference between measured coordinates is 2345 meters.

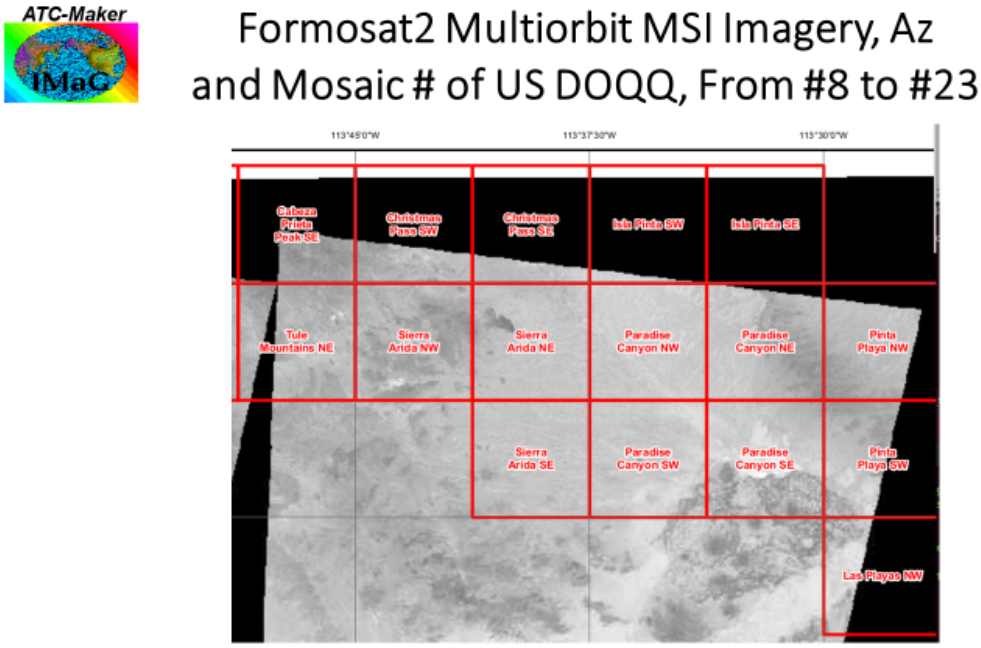

Figure 6. A portion of Formosat-2 mosaic #2 and corresponding DOQQs.

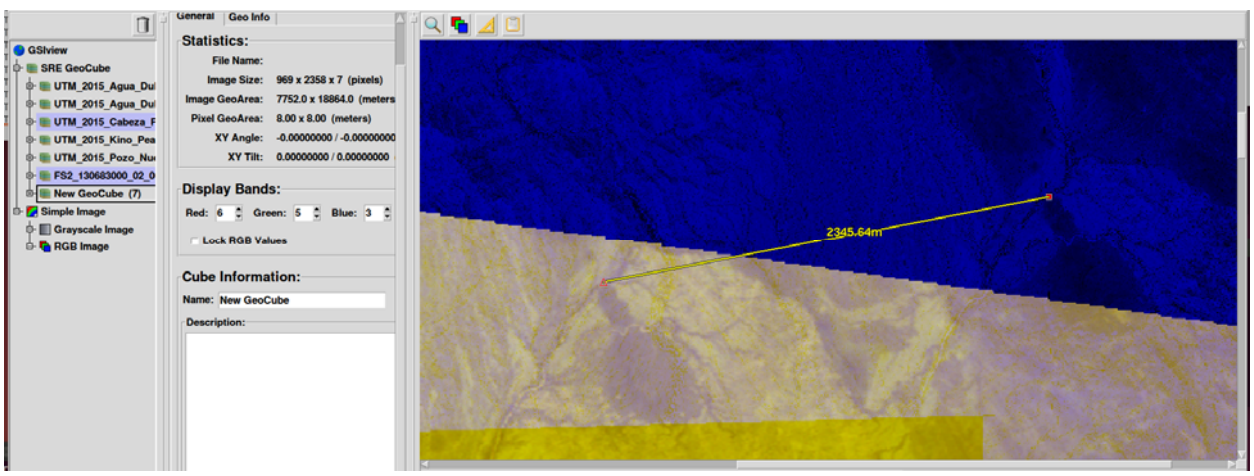

Figure 7. Comparison of a landmark from Formosat-2 mosaic #2 and DOQQs. The measured spatial shift between these two landmarks is 2345 m.

Mosaic #3

Figure 8 shows a portion of the Formoast-2 mosaic #3 image and DOQQs. An identifiable landmark (a unique turn in railroad) was visually identified. Coordinates were measured from both mosaicked Formosat-2 images and DOQQs, as shown in figure 9. The difference between measured coordinates is 1856 meters.

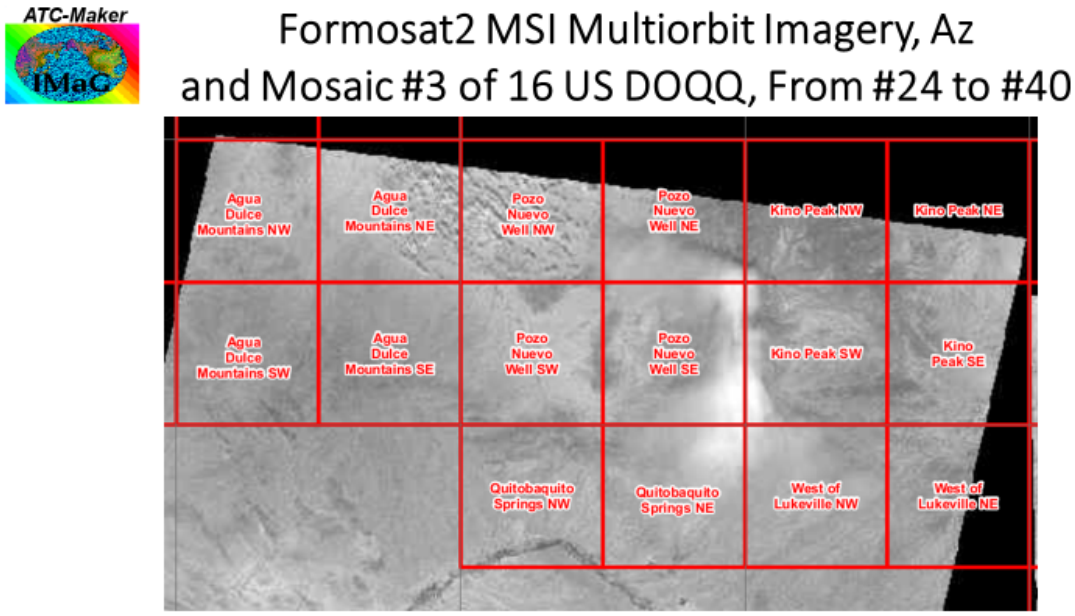

Figure 8. A portion of Formosat-2 mosaic #3 and corresponding DOQQs.

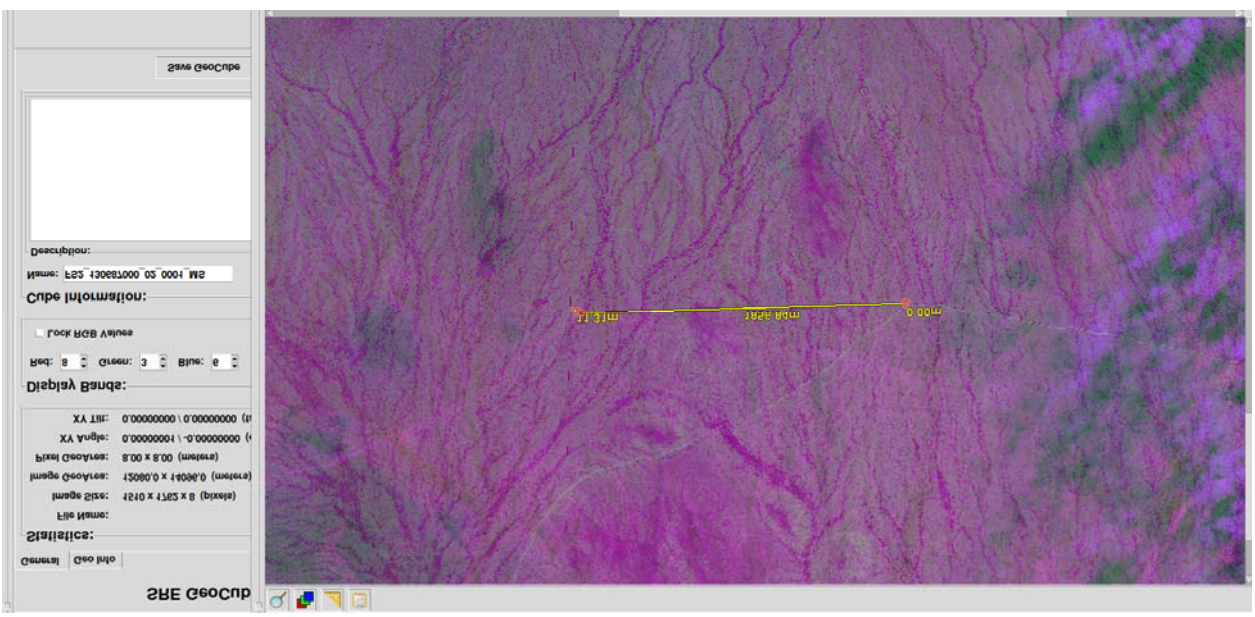

Figure 9. Comparison of a landmark from Formosat-2 mosaic #3 and DOQQs. The measured spatial shift between these two landmarks is 1856 m.

Mosaic #4

Figure 10 shows a portion of the Formoast-2 mosaic #4 image and DOQQs. An identifiable landmark (merge of two rivers) was visually identified. Coordinates were measured from both mosaicked Formosat-2 images and DOQQs, as shown in figure 11. The difference between measured coordinates is 274 meters.

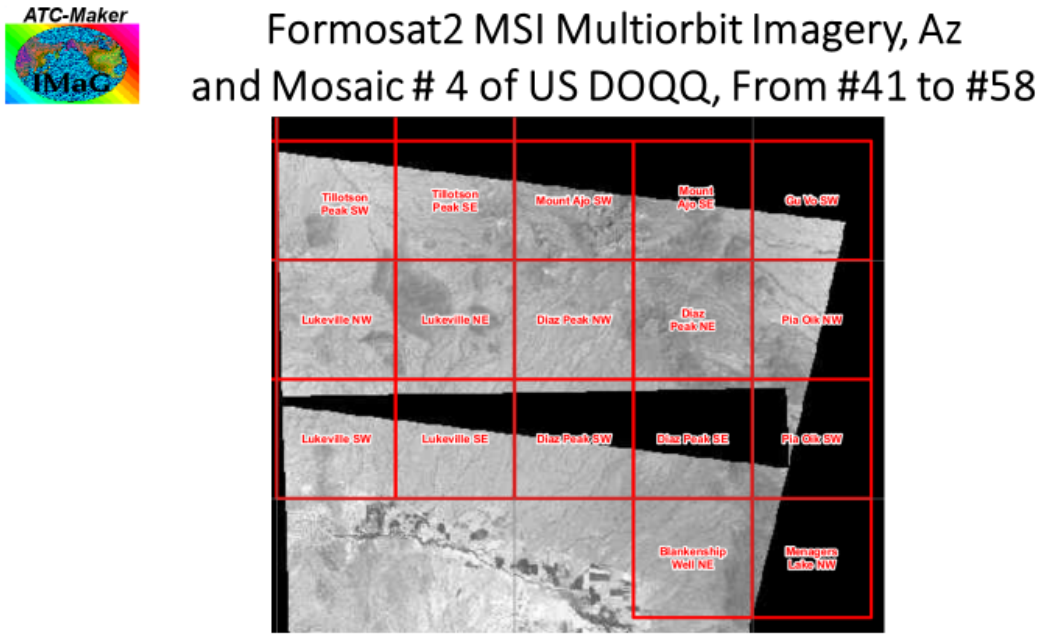

Figure 10. A portion of Formosat-2 mosaic #4 and corresponding DOQQs.

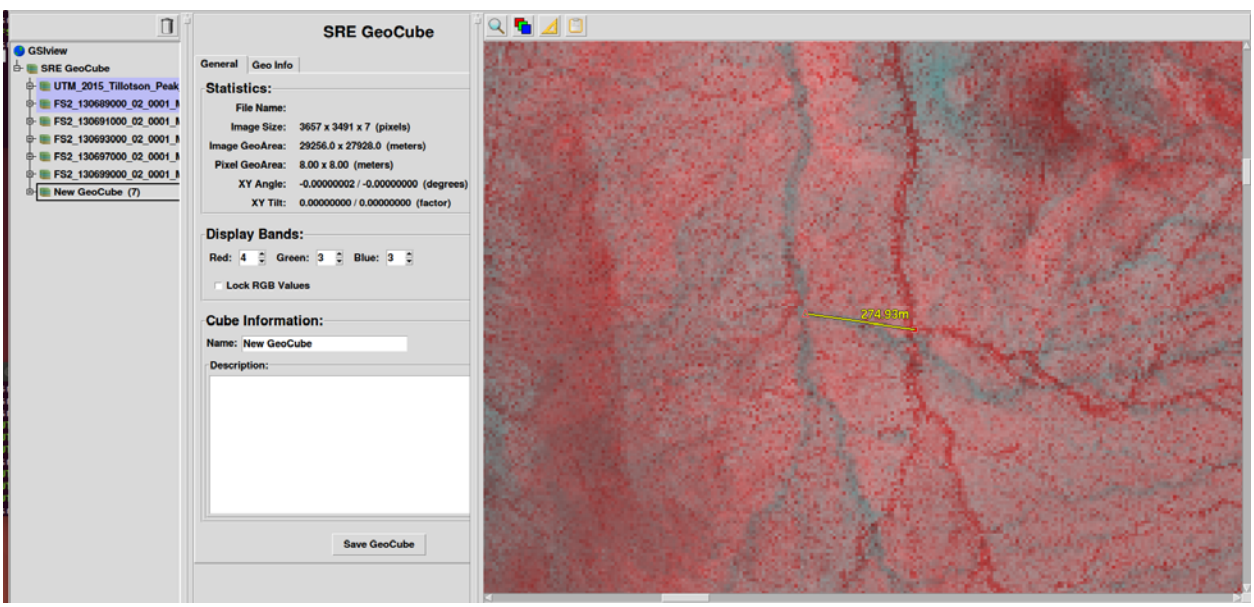

Figure 11. Comparison of a landmark from Formosat-2 mosaic #4 and DOQQs. The measured spatial shift between these two landmarks is 274 m.

SPATIAL ACCURACY OF FORMOSAT-2 IMAGES IN ARIZONA BASED ON GOOGLE EARTH PRO

In addition to using DOQQ as the location reference, Google Earth Pro imagery was used as another location reference. The example landmark used in Formosat-2 mosaic #1 was used again in this assessment, as shown in Figure 12. The differences between coordinates measured from Formosat-2 mosaic #1 and Google Earth Pro imagery is 2307 meters. Compared to 2297 meters between Formosat-2 mosaic #1 and DOQQ, there is only 10 meters in difference.

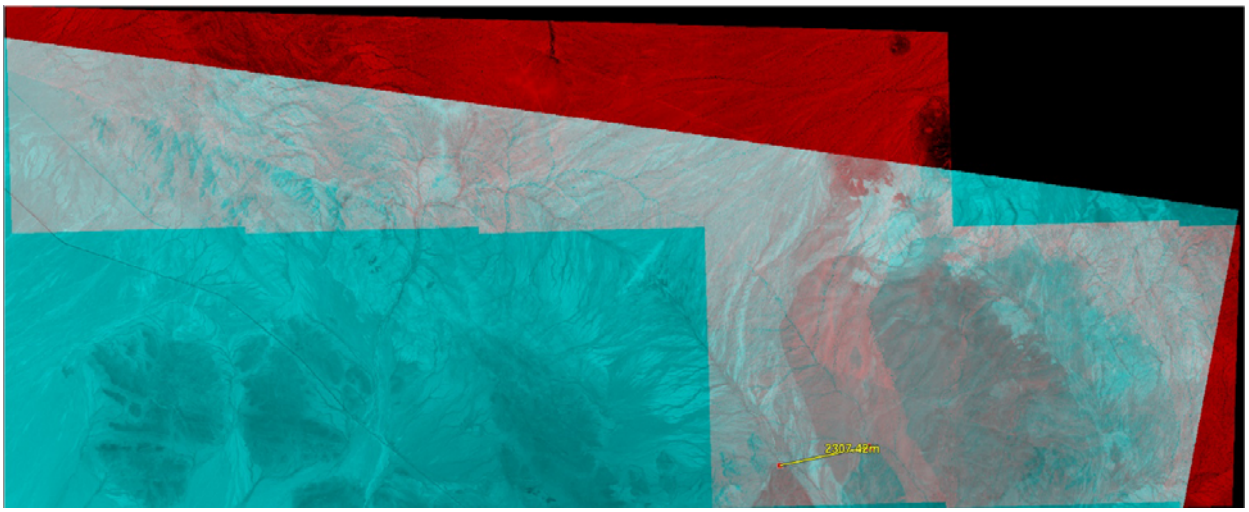

Figure 12. Formosat-2 mosaic #1 landmark compared to Google Earth Pro imagery. The difference in coordinates is 2307 meters.

Knowing the large offset on the coordinates, either based on DOQQ or Google Earth Pro, an attempt was made to minimize such offset. The function iMaG AGR, an automated georegistration software system by Susquehanna Resources and Environment, Inc (SRE) was utilized to automatically align Google Earth Pro and Formosat-2 mosaic #1. The result is a perfect match as shown in Figure 13, with 0 meter offset between corrected Fomrosat-2 mosaic #1 and Google Earth Pro.

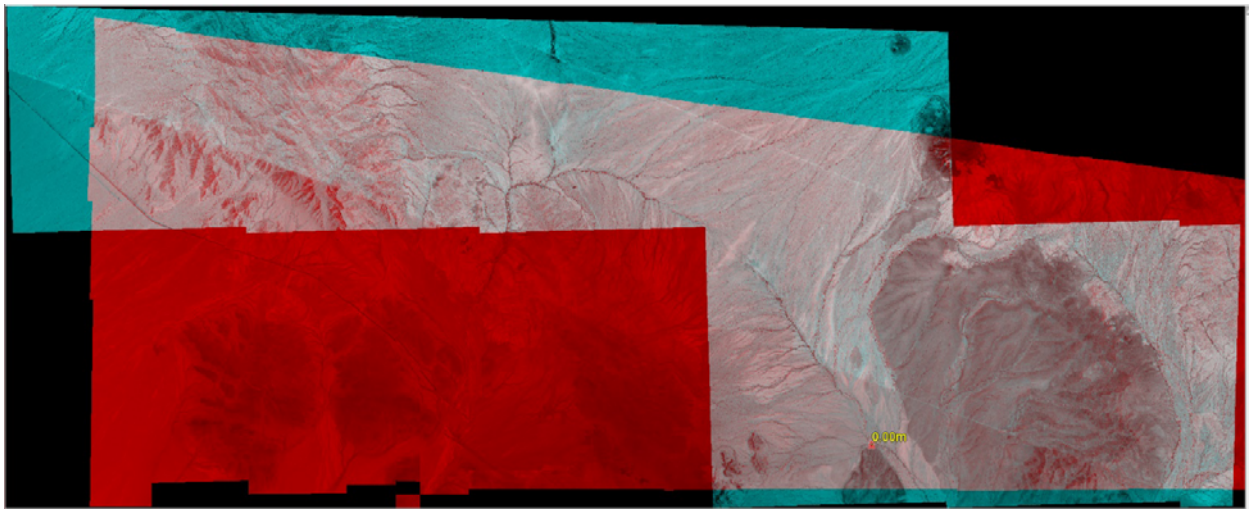

Figure 13. Corrected Formosat-2 mosaic #1 based on Google Earth Pro, with 0 meter offset.

CONCLUSION

In this paper, we have examined the spatial accuracy of Formosat-2 imagers of Wulai Mountain, Taipei Taiwan and Southern Arizona, USA. We found that multi-orbit Formosat-2 imagery on Taiwan has an excellent geospatial accuracy (0 meter offset found in this study), while Formosat-2 images of southern Arizona, USA have offset ranging from 28m to 3110m when they are matched against the United States DOQQ of the same region.

For the reference/base to Formosat-2 imagery outside Taiwan, we suggest the use of Google Earth Pro imagery because of a close match between DOQQ and Google Earth Pro geospatial accuracy, as observed in Formosat-2 mosaic #1 region. This study serves as a benchmark for the geospatial accuracy of Formosat-2, as well as a potential reference for the expected Formosat-5.

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