Standard Operation Procedure Development of FORMOSAT-2/5 Analysis-Ready Data

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ABSTRACT: At present Analysis-Ready Data (ARD) has become a standard format of satellite image products. ARD is not only easy to use for general users but also important for time-series analysis. All FORMOSAT-2/5 ARD produced by National Space Organization (NSPO) is derived by FORMOSAT-2/5 level-4 products, which have been spatial aligned and radiometric calibrated. A standard FORMOSAT-2/5 ARD set includes Top of Atmosphere Reflectance (TOAR) and Quality Index (QI). The QI actually is the cloud mask derived by cloud detection approach with Automatic Cloud Cover Assessment (ACCA) and image segmentation. In NSPO, standard operation procedure for the generation of FORMOSAT-2/5 ARD has been established and provided by the data service platform Taiwan Data Cube (TWDC). Currently, a formal Computer Software Unit (CSU) is under development to integrate the producing procedure of FORMOSAT-2/5 ARD to the next generation Data Processing Subsystem (DPS) of Image Processing System (IPS). In the future, FORMOSAT-2/5 ARD will be a standard product of NSPO and can be accessed by general users.

1. INTRODUCTION

Remote sensing is a powerful technology to record the changing environment. It can be applied in various fields. However, the integration of remote sensing data from different periods and sensors is key issue on multi-source and multi-temporal applications. However, pre-processing of raw products of remote sensing data acquired from different sources is a huge barrier for general users. Therefore, Analysis-Ready Data (ARD) is proposed by Committee on Earth Observation Satellites (CEOS) (Lewis, et al., 2018.).

The paper presents the development of FORMOSAT-2/5 ARD, which now is only available in Taiwan Data Cube (TWDC) that will become a standard product of National Space Organization (NSPO). In addition, the integration of the producing procedure of FORMOSAT-2/5 ARD to the next generation's Data Processing Subsystem (DPS) of Image Processing System (IPS) of NSPO is also discussed in the following sections.

1.1 Analysis-Ready Data

A geometric and radiometric calibrated remote sensing data can be referred as ARD. General users can directly apply ARD in their applications without pre-processing. It makes ARD a standard product of remote sensing data nowadays. More and more satellite data providers started to provide remote sensing data in ARD format, such as USGS and ESA… etc (USGS, 2018 and ESA, 2021).

Currently NSPO also developed procedures to generate ARD of FORMOSAT-2/5 optical images including TOAR and QI based on a cloud detection scheme (Liao. Chang, Wei & Chen, 2020). The potential integration in the ARD by various satellite sensors for multi-temporal and multi-source applications has been validated on TWDC (Cheng, Chiou, Chen, Liu, Lin, Shih, Chung, Lin & Chou, 2019).

1.2 Taiwan Data Cube

NSPO developed and operated TWDC based on Open Data Cube (ODC), which is an advanced data service that can store, integrate and process multi-temporal, multi-dimensional and multi-source ARD on a single platform promoted by The Committee on Earth Observation Satellites (ODC, 2021).

NSPO improved the flexibility of data and user management on TWDC. Now, TWDC is a set of many cubes with different policy for different users on a supercomputer, Taiwan Computing Cloud (TWCC) (Liao, Chang & Wei, 2021).. A public cube of TWDC contains open source data such as Sentinel-1/2 and Landsat-7/8 ARD. A commercial cube on TWDC contains FORMOSAT-2/5 ARD. For some remote sensing data providers, they can build their own private cube with their own ARDs.

1.3 IPS and DPS

IPS was developed by NSPO for daily operation of FORMOSAT series optical images. There are five subsystems in IPS (Fig. 1): Planning and Scheduling Subsystem (PSS) for image tasking, Data Ingestion Subsystem (DIS) for image data acquisition, Data Processing Subsystem (DPS) for image data processing, Data Management Subsystem (DMS) for image data management and Image Quality Subsystem (IQS) for quality maintenance of image data (Chang, Kuo. Chou. Hsu, Yan, Hwang & Liu, 2016 and Wu & Chang, 2014). The PSS, DIS and IQS are for operating missions only. Therefore, only DMS and DPS works for the archive data of decommissioned FORMOSAT-2.

DPS, part of IPS, produces standard image products for end users. The DPS performs key pre-processing computations which include radiometric equalization and geometric rectification operations. In addition, the DPS attaches to each standard image product an auxiliary data set as dimap file, containing information usually required for various remote sensing applications. Based on the needs of his or her applications, an end user may request a level 1A, level 2, or level 4 pre-processed image product (NSPO, 2020).

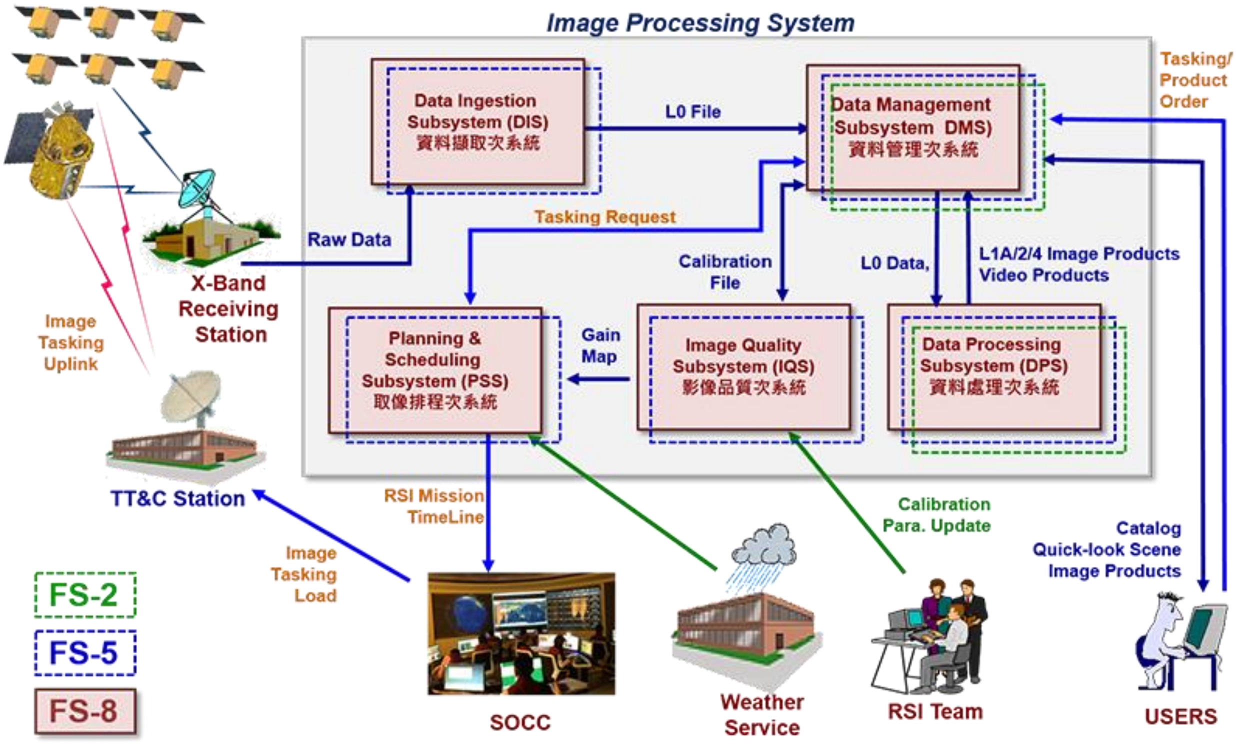

Figure 1. The System Architecture of IPS.

1.4 FORMOSAT-2/5

FORMOSAT-2 is the first operational remote sensing satellite owned by NSPO. It was launched on May 21,2004 and decommissioned on August 19, 2016. The primary payload onboard FORMOSAT-2 is Remote Sensing Instrument (RSI), with 2-meter ground sample distance (GSD) in panchromatic (PAN) band and 8-meter GSD in multi-spectral bands (Wu et al., 2014). The orbit design made FORMOSAT-2 revisit Taiwan area daily.

FORMOSAT-5, the successor of FORMOSAT-2 carries a CMOS RSI with 2-meter GSD in PAN and 4-meter GSD in MS is the first domestic optical remote sensing satellite developed by NSPO. It was launched on August 25, 2017. Unlike FORMOSAT-2, FORMOSAT-5 has 2-day repeatability for global coverage.

2. FORMOSAT-2/5 ARD PRODUCTION

The current ARD production of FORMOSAT-2/5 is in operational phase. All the data flow is controlled by the main sequence. The main sequence scans the product folder regularly to find workorders with standard level-4 products from DPS of IPS and transforms them into ARD format (Fig. 2 and Fig. 3).

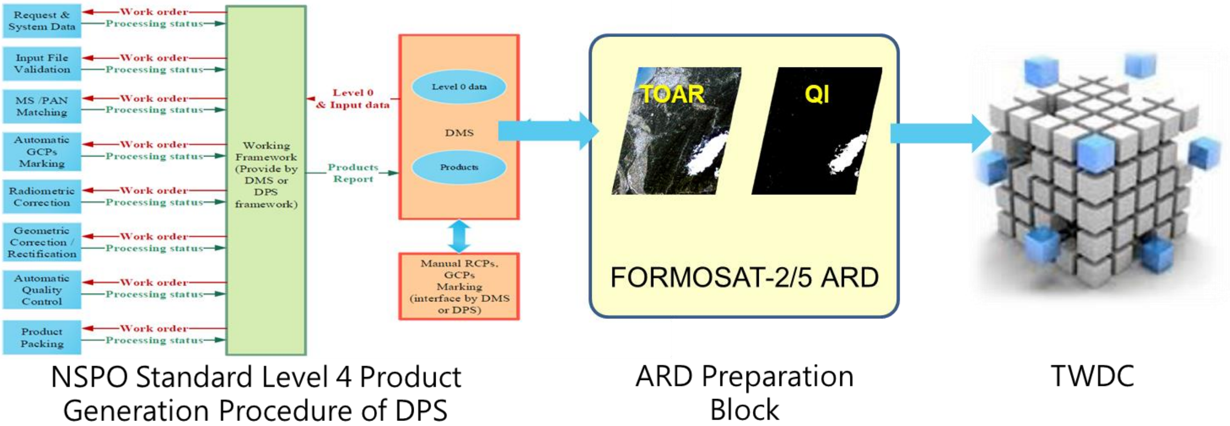

Figure 2. The data flow of current FORMOSAT-2/5 ARD production from DPS to TWDC (Liao. Chang, Wei & Chen, 2020)

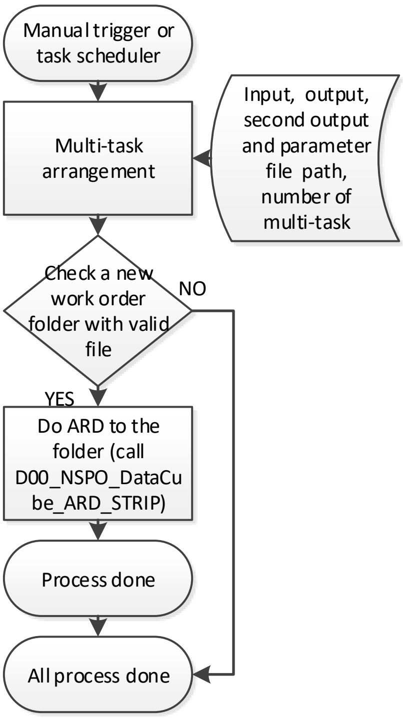

Figure 3. The mechanism of current FORMOSAT-2/5 ARD production in workorder folder control. (NSPO, 2019)

And the sub sequence includes 2 parts (Fig. 4). First, the TOAR conversion for source image from standard FORMOSAT-2/5 level-4 product. Second, the cloud detection will apply on the TOAR image and output a QI. The output ARD will be compressed, packed and transmitted by SFTP to TWDC server when TWDC option is enabled (Wei, Chang & Hsu, 2021).

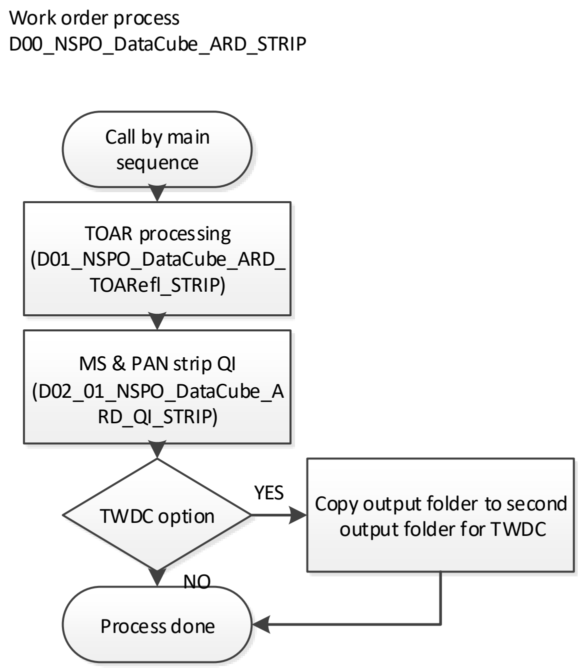

Figure 4. The current FORMOSAT-2/5 ARD production procedure of each workorder. (NSPO, 2019)

2.1 TOAR conversion

TOAR conversion plays an important role to convert raw digital count image into reflectance image with spectral characteristic for further processing in spectral domain (Fig. 5). Every observation by FORMOSAT-2/5 is in strip image. However, the delivery of standard product is in grid image. Thus, the first process in TOAR is to mosaic the standard level-4 product in to a strip. Then, the radiometric coefficient and solar geometry from dimap file is applied on the grey level image and converts into a strip TOAR image by the equation 1 (Teillet, Barker, Markham, Irish, Fedosejevs & Storey, 2001):

$$\rho = \frac{\pi * L * d^2}{ESUN * cos\theta_s} \dots (1)$$

Where L for spectral mean radiance observed by a satellite. d for sun-earth distance. ESUN for Solar Exoatmospheric Spectral irradiance. θ_s for solar zenith angle.

After the strip TOAR image is done, the Geospatial Data Abstraction Library (GDAL) crops the strip image into original extent as grids as the final TOAR output.

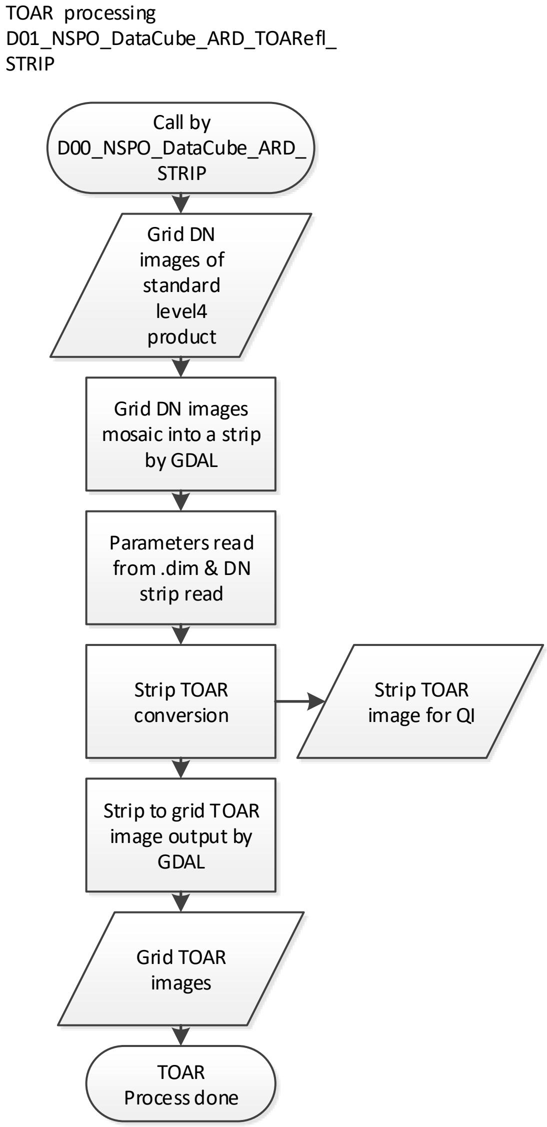

Figure 5. The current FORMOSAT-2/5 ARD production procedure of TOAR conversion. (NSPO, 2019)

2.2 QI

The previous version of QI was grid based (Liao, Chang, Chang & Chen, 2019). But the cloud patterns showed the discontinuity in the image edge of adjacent gird due to the different pixel for region growing segmentation (Adams & Bischof, 1994 and Gonzalez & Woods, 2018) to start. The current QI is based on the TOAR strip image done by the TOAR conversion (Fig. 6).

For MS QI, the ACCA (Hsu, Chang & Yu, 2015) result of MS TOAR strip image is only for the spectral threshold estimation of cloud. Meanwhile, use the region growing to segment the MS TOAR strip image. The segmentation procedure makes the cloud detection under a segment based to avoid a fragmentary QI.

The result of segmentation is filtered by ACCA threshold as the solid cloud. The solid cloud is filtered by erosion operation of morphology to avoid some bright non-cloud objects. Besides, the result of segmentation is also filtered by a partial ACCA threshold as the potential cloud. The union of the solid cloud and the potential cloud is filtered again by morphology operation to get a complete MS cloud strip as QI.

For PAN QI, it is similar procedure but without image segmentation. If the MS strip QI in same area is overlapped, it will cover the PAN QI as the final PAN strip QI to maximum the advantage of MS image in cloud detection. All strip QI is cropped into original extent as grids by GDAL.

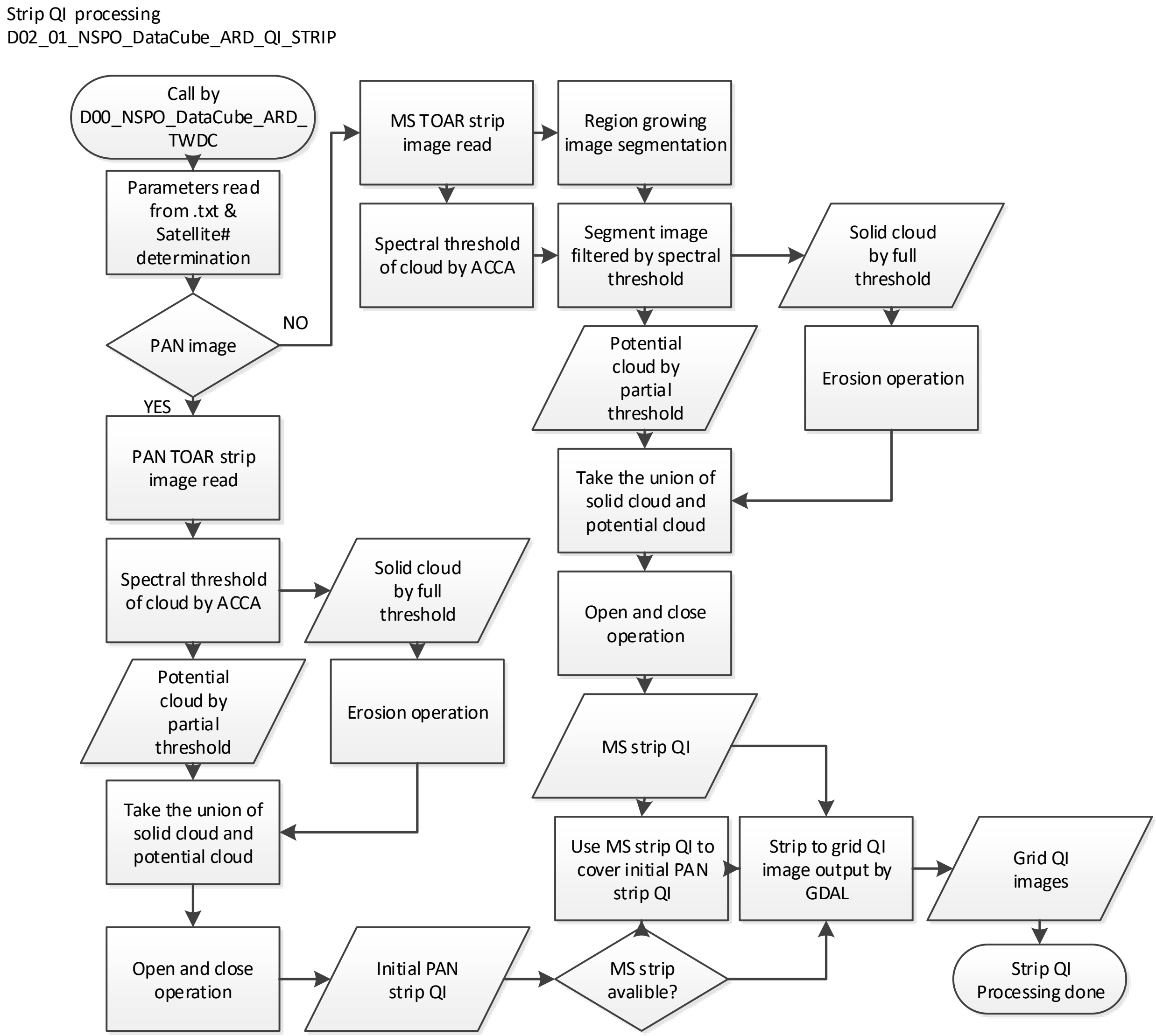

Figure 6. The current FORMOSAT-2/5 ARD production procedure of QI based on a cloud detection. (NSPO, 2019

2.3 Hardware

The operational ARD production of FORMOSAT-2/5 is deployed on a HP Z8 work station (the spec of the work station is shown on Table 1) (Liao et al., 2021). For each standard level4 product bundle (a bundle image set includes a PAN and a MS images in grid). It only takes less than 5 minutes to produce them into ARD format in average. By enlarging Random Access Memory (RAM) size, the work station can produce more workorders at the same time to maximize production capacity.

Table 1. Spec of ARD Preparation Work Station

Item	Detail
CPU	Intel Xeon 4215R 3.2GHz x2
Graphics	NVIDIA Quadro P5000 16GB
RAM	128GB (4x32GB) DDR4 2933 ECC RAM
SSD	1TB M.2 2280 PCIe NVMe TLC Solid State Drive

HDD	WD / 101EFBX 10TB x2
OS	Windows 10 Pro 64 Workstations Plus TW

3. APPLICATIONS OF FORMOSAT-2/5 ARD

3.1 Customized Mosaic based on QI by TWDC

On TWDC, Users can specify time period and location. And TWDC mosaics an image with the minimum cloud coverage and no data pixels to maximize clear pixel (Fig. 7). It shows on TWDC interface and also can be exported as geotiff file for off-line application.

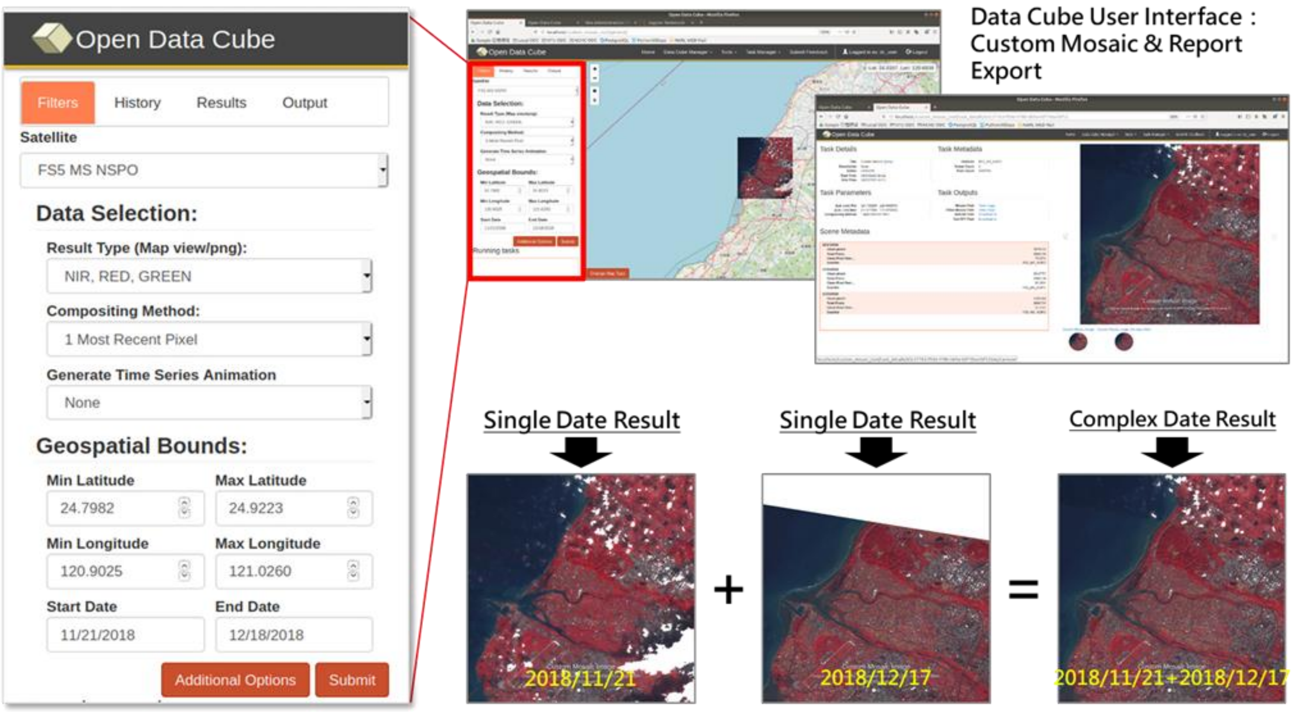

Figure 7. TWDC user interface for customized mosaic. (Liao et al., 2020)

3.2 Paddy Rice Detection based on TOAR by TWDC

Paddy rice starts growing in spring after land preparation in winter in central Taiwan, some farmers grow green manure to gain nutrient when land is in preparation.

In paddy rice detection on TWDC, two periods images are required (Fig. 8). Prior period image in winter and later period image in spring are for change vector analysis based on spectral distance and angle, NDVI and NDWI (Chang, Tsai, Guo, Wang, Liu & Chang, 2018).

The TOAR has been radiometric calibrated and converted to remove different solar geometry in time series. This makes TOAR be consistent in spectral. The similar patterns between two year's paddy rice detection tell the necessity of TOAR in multi-temporal applications (Fig. 9).

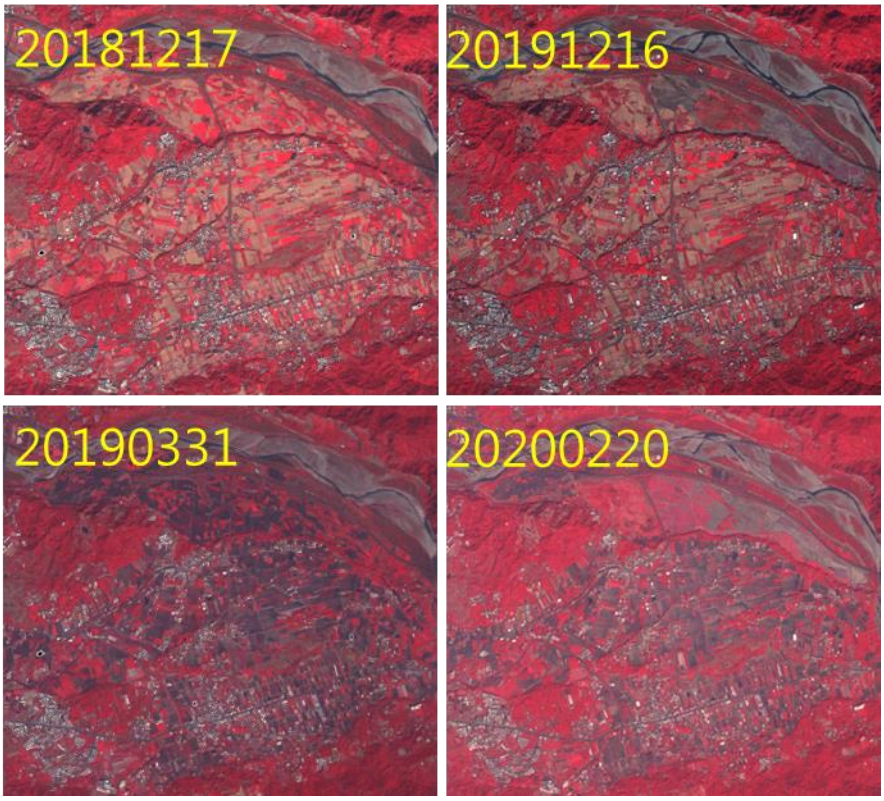

Figure 8. Two sets of images for the paddy rice detection. Left column for winter, 2018 and spring, 2019. Right column for winter, 2019 and spring, 2020. (Liao, et al., 2020)

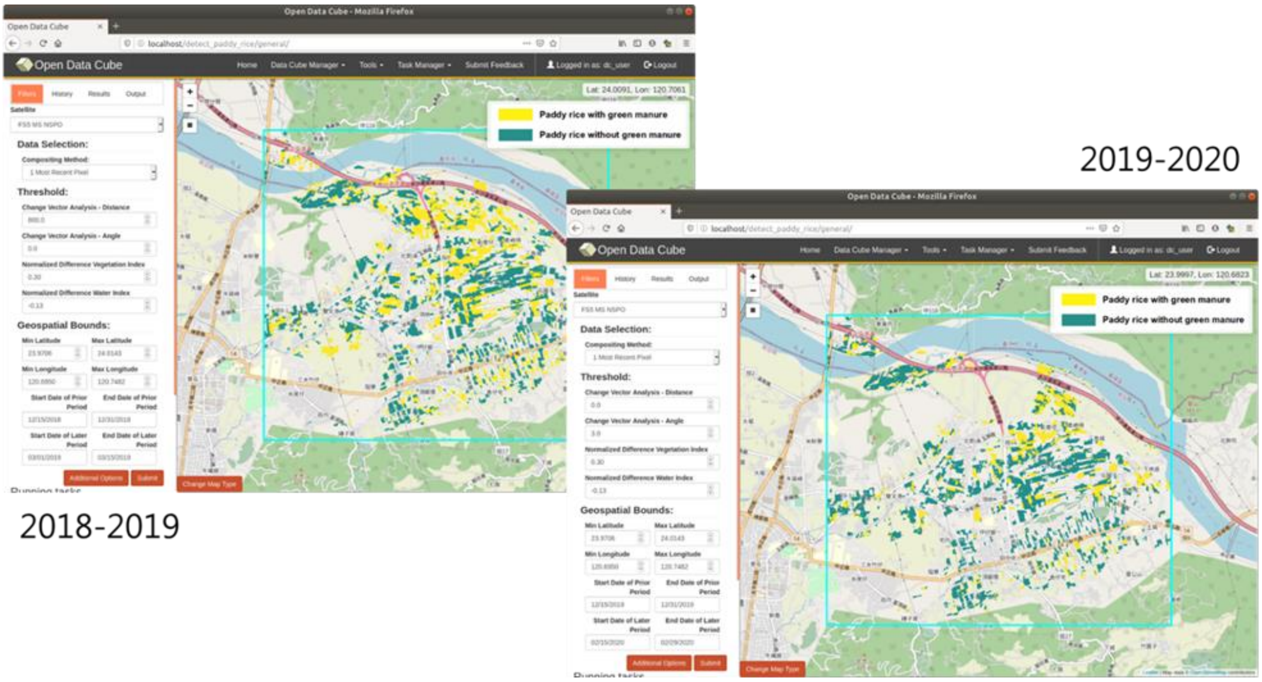

Figure 9. Online processing results of the paddy rice detection on TWDC. (Liao et al., 2020)

3.3 Panama Disease Prevention

Banana is one of most common cash crop in regions with tropical climate. Global supply of banana came under the threat of Tropical Race 4 (TR4), a new strain of fungus Fusarium oxysporum f.sp cubense (FOC) that causes Fusarium wilt (as known as Panama Disease) since 2020 (TAIWAN ICDF, 2020).

NSPO develops an early warning and notification system for large-scale Foc TR4 infections in central America with International Cooperation and Development Fund (Taiwan ICDF) (TAIWAN ICDF, 2022). The system is based on spectral indexes such as Normalized Difference Vegetation Index (NDVI) derived from ARDs of Sentinel-2 and FORMOSAT-5.

The system uses Sentinel-2 ARD for regular monitoring. Once anomaly is detected in regular monitoring, FORMOSAT-5 is tasked to acquire higher resolution image to reveal the spatial details for the affected areas (Fig. 10). Then, the corresponding result is provided to Taiwan ICDF and used as a reference to carried out field investigation (Fig. 11).

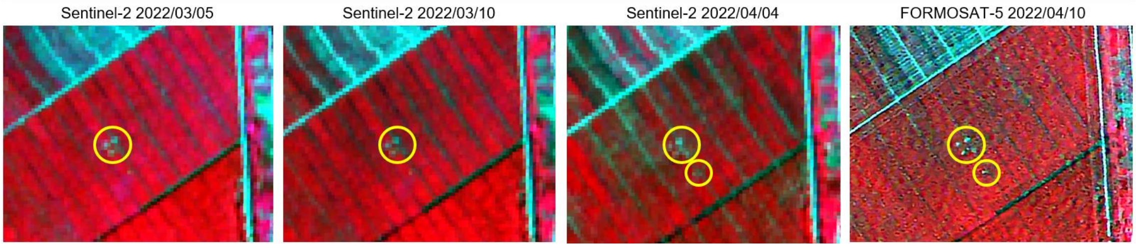

Figure 10. Images of regular monitoring by Sentinel-2. When anomaly detected (yellow circle) for days, FORMOSAT-5 was scheduled to take an image for more details in spatial. (Chang, Cheng, Wang, Villela, Euceda & Wei, 2021)

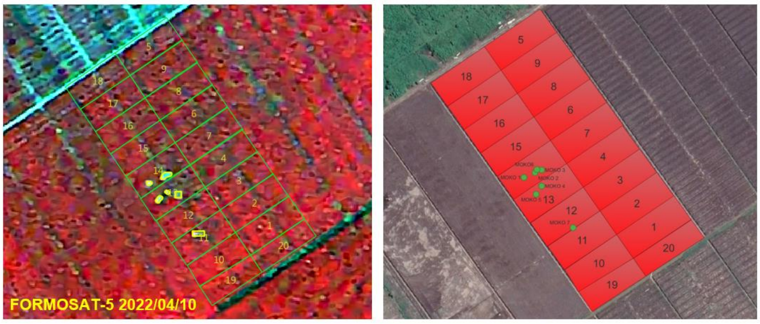

Figure 11. FORMOSAT-5 ARD for identifying anomaly and proving as a reference for field investigation (yellow edge patterns on left image). Field investigation result carried out by ICDF (green spots on right image). (Cheng et al., 2021)

4. CONCLUSION AND FUTURE WORK

The FORMOSAT-2/5 ARD including TOAR and QI developed by NSPO shows not only great potential in many applications but also the importance of ARD in multi-temporal and multi-source analysis. The ARD production procedure now is in operational phase and provides FORMOSAT-2/5 ARD in TWDC currently. The stability of whole system has been validated for years and in various applications. The standard operation procedures of producing FORMOSAT-2/5 ARD product will be integrated in the next generation DPS of IPS. After FORMOSAT-2/5 ARD become a standard product of NSPO, more general users can perform their own applications without pre-processing. NSPO will keep improving the performance of ARD generation and developing higher level products like ARD to meet the needs of users on FORMOSAT series satellite images.

5. REFERENCES

Chang, L. H., Y. L. Kuo, S. C. Chou, K. H. Hsu, S. Y. Yan, F. T. Hwang & C. Liu, 2016. Image Processing System of FORMOSAT-5. The 37th Asian Conference on Remote Sensing (ACRS), Oct. 17-21, Colombo, Sri Lanka.

Chang, L. Y., F. A. Tsai, H. Y. Guo, H. H. Wang, C. Liu, & L. H. Chang, 2018. A Phenology Based Approach for Rice Field Detection Using Multi-sensor and Multi-temporal High Resolution Satellite Images, The 37th Conference on Surveying and Geoinformatics, 4-5 Sep., Taoyuan, Taiwan.

Chang, L. Y., K. M. Cheng, H. C. Wang, M. Villela, X. Euceda, & H. C. Wei, 2021. Massive Area Disease of Plants in Central America by Using Multi-sensor and Multi-temporal Satellites' Image on Data Cube, The 39th Conference on Surveying and Geoinformatics, 28-29 Oct., New Taipei, Taiwan.

Cheng, M. C., C. R. Chiou, B. Chen, C. Liu, H. C. Lin, I. L. Shih, C. H. Chung, H. Y. Lin & C. Y. Chou, 2019. Open data cube (ODC) in Taiwan. IGARSS 2019-2019 IEEE International Geoscience and Remote Sensing Symposium.

IEEE.
Hsu, K.-H., H.-P. Chang, S.-J. Yu. 2015. The Preliminary Development of FORMOSAT-5 Automatic Cloud Coverage Assessment Method. International Symposium on Remote Sensing, April 22-24, Tainan, Taiwan.
Lewis, A., J. Lacey, S. Mecklenburg, J. Ross, A. Siqueira, B. Killough, Z. Szantoi, T. Tadono, A. Rosenavist, P. Goryl, N. Miranda, & S. Hosford. 2018. "CEOS analysis ready data for Land (CARD4L) overview." IGARSS 2018-2018 IEEE International Geoscience and Remote Sensing Symposium. IEEE.
Liao, T. U., L. Y. Chang, H. C. Wei, & N. Y. Chen, 2020. Production and Application of Analysis-ready Data on Taiwan Data Cube. International Conference on Astronautics and Space Exploration (iCASE), November 14, Hsinchu, Taiwan
Liao, T. U., L. Y. Chang & H. C. Wei, 2021. . An Automatic Approach for the Preparation of FORMOSAT-2/5 ARD. International Conference on Astronautics and Space Exploration (iCASE), November 16-18, Hsinchu, Taiwan
Liao, T. Y., L. Y. Chang, L. H. Chang, & N. Y. Chen, 2019. Cloud Coverage Detection of FORMOSAT-5 Image Product Based on Image Segmentation and Morphology, The 38th Conference on Surveying and Geoinformatics, 29-30 Aug. 2019, Taoyuan, Taiwan.
NSPO, 2019. FORMOSAT-8 IPS System Software Design Document
NSPO, 2020. Image Processing System, Retrieved Aug. 29, 2022, from https://www.nspo.narl.org.tw/ground_fac.php?c=20031001&ln=en
R. Adams, L. Bischof, 1994. "Seeded region growing", IEEE Trans. Pattern Anal. Machine Intell., vol. 16, pp. 641-647.
R. Gonzalez and R. Woods, 2018. Digital Image Processing, Global Edition. Harlow, United Kingdom: Pearson Education Limited.
TAIWAN ICDF, 2020. Panama Disease Epidemic - TaiwanICDF helps Central American Friendly Nations from going “Bananas”, Retrieved Aug. 29, 2022, from https://www.icdf.org.tw/wSite/ct?xItem=58503&ctNode=31572&mp=2
TAIWAN ICDF, 2022. The Taiwan ICDF and International Regional Organization of Agricultural Health (OIRSA) jointly protect the banana industries of diplomatic allies, Retrieved Aug. 29, 2022, from https://www.icdf.org.tw/wSite/ct?xItem=68774&ctNode=31572&mp=2
Teillet, P. M., Barker, J. L., Markham, B. L., Irish, R. R., Fedosejevs, G., & Storey, J. C. 2001. Radiometric cross-calibration of the Landsat-7 ETM+ and Landsat-5 TM sensors based on tandem data sets. Remote sensing of Environment, 78(1-2), 39-54.
Wei, H. C., L. Y. Chang & C. W. Hsu, 2021. An Automated ARD Transmission and Ingestion in TWDC. International Conference on Astronautics and Space Exploration (iCASE), November 16-18, Hsinchu, Taiwan
Wu, A. M. & Chang, G. S., 2014. FORMOSAT-2 Image Processing System Development and Outlook. Journal of Photogrammetry and Remote Sensing, 18(1), 1-12.
ODC, 2021. An Open Source Geospatial Data Management & Analysis Platform, Retrieved Aug. 29, 2022, from https://www.opendatacube.org/
USGS, 2018. Landsat Collection 2 U.S. Analysis Ready Data, Retrieved Aug. 29, 2022, from https://www.usgs.gov/landsat-missions/landsat-collection-2-us-analysis-ready-data
ESA, 2021. Copernicus Sentinel-2 data products, Retrieved Aug. 29, 2022, from https://sentinel.esa.int/web/sentinel/sentinel-data-access/sentinel-products/sentinel-2-data-products