QUALITY VERIFICATION OF OVERALL PLANNING SATELLITE REMOTE SENSING IMAGES PRODUCT FOR REAL 3D CHINA CONSTRUCTION PROJECT

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ABSTRACT:

The overall planning of satellite remote sensing image products is an important part of the real 3D China construction project and an important measure for the overall management of remote sensing images. During the two years of implementation of the project in 2021 and 2022, we have organized and completed 9 versions of 2-meter resolution satellite remote sensing image products, each of which covers the land territory of the whole country (not less than 95% in principle). Image products are widely used in natural resources investigation and monitoring, basic surveying and mapping, geological survey, natural resources supervision, law enforcement and other fields, which effectively improves the guarantee capability of surveying and mapping geographic information services. Taking the 2022 2-meter resolution integrated satellite remote sensing image product as the research object, this paper first introduces the highlights of the product itself, that is, timeliness, availability and reliability. then the product quality is studied from six aspects: spatial reference system, position accuracy, logical consistency, time accuracy, image quality and attachment quality. On this basis, according to the characteristics of different geographical regions, seasonal time series, topography and geomorphology, 100 representative verification samples were selected from the overall satellite remote sensing image products in 2022 for experiments, the distribution law of product quality characteristics was analyzed, and the main quality problems were summarized.

1. INTRODUCTION

1.1 Data Overview

2m resolution overall planning satellite remote sensing image products take better than 2.5m resolution satellite remote sensing images as data sources, mainly including: ZY-3 (01/02/03), GF1, GF1 2m / 8m satellite, GF6, ZY-1 02D/02E, CB 04A and other satellites.

The product data content consists of the whole scene multi-spectral image file, the whole scene panchromatic image file, the whole scene RGB fusion image file, the projection information file recording the image projection information and the metadata file.

1.2 Technical Procedure

By using orthophoto images with accuracy better than 1:25000 scale within the national boundary, orthophoto image control data with accuracy better than 1:50000 scale outside the national boundary, and DEM data with a grid spacing of 10 meters in the land of the whole country, based on the existing satellite remote sensing software, the control points and connection points of satellite images are obtained by image feature matching or artificial thorn points, and the high-precision external parameters are calculated after adjustment. Through orthophoto correction, image registration, image fusion, image enhancement and other processes to produce image products that meet the accuracy.

2. PRODUCT HIGHLIGHT

2.1 Timeliness

The time phase of the original satellite remote sensing image is divided according to the natural month, and the production of one edition is completed every three months and four editions a year.

Version	Resolution(m)	Satellite Image Phase
First Quarter	2.0、2.1、2.5	From January 1 to March 31, 2022
Second Quarter	2.0、2.1、2.5	From April 1 to June 30, 2022
Third Quarter	2.0、2.1、2.5	From July 1 to September 30, 2022
Fourth Quarter	2.0、2.1、2.5	From October 1 to December 31, 2022

Table 1. Phase requirements for satellite remote sensing images (take 2022 as an example).

2.2 Availability

Cloud cover index is an important factor in quality inspection and evaluation of optical satellite remote sensing image products, and it is also an important factor affecting image quality judgment. The existence of cloud spots makes it difficult to identify and classify the underlying surface objects and to extract, calculate and apply remote sensing image information. Cloud patches can be divided into thick cloud, thin cloud, thin cloud, haze, cloud shadow and other types due to their different

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optical thickness, geometric shape, texture characteristics and spatial distribution. The cloud cover index mentioned in this paper refers to the ratio of the sum of the affected area of cloud cover in the evaluated optical satellite remote sensing image product to the total area of the image product, which is usually expressed as a percentage.

The cloud cover per scene of the original satellite image does not exceed 20%.

2.3 Reliability

When combined with high-precision reference images, the error in the combination of flat land and hilly land does not exceed 5 meters, and that of mountains and high mountains does not exceed 8 meters. For offshore areas and large area single feature areas, for example, water bodies, forests, grasslands, Gobi, etc., the RMSE can be appropriately relaxed, the maximum RMSE shall not exceed 1.5 times, and the maximum error shall not exceed 2 times.

Terrain Types	RMSE (m)
Flat Land or Hilly Land	5
Mountain Area or High Mountain Area	8

Table 2. Mean square error for different terrains

3. VERIFY CONTENT AND TECHNICAL INDEX REQUIREMENTS

3.1 Spatial Reference System

3.1.1 Verification Content: Check the correctness of the parameters of coordinate system and map projection.

3.1.2 Technical Index Requirement: The coordinate system is National Geodetic coordinate System 2000 (CGCS2000); Gauss-kluge projection was adopted, the standard 6° zoned, and the coordinate unit was meters. No projection tape number is added before the horizontal coordinate of the image. When the whole scene corrects the image across the tape, the projection belt with more image distribution should be taken as the projection belt of the whole scene correction.

3.2 Position Accuracy

3.2.1 Verification Content: Check the error in the plane position, the registration error of multi-spectral and panchromatic orthophoto images, and whether the offset limit difference of the points with the same name on the adjacent scene meets the accuracy requirements.

3.2.2 Technical Index Requirement: The in-fit error is described in the previous section. Image registration: After the registration of panchromatic band image and multi-spectral image, the matching check should be carried out. The registration accuracy between the two types of image shall be no more than 0.5 pixel (on multi-spectral image), and the maximum error shall be no more than 1 pixel (on multi-spectral image). Typical ground objects and topographic features (such as valley and ridge) shall not have double shadows.

3.2.3 Verification Method: Position accuracy check is carried out by comparison of existing reference images, high-precision data results or high-precision control point data. Select about 20-50 ground feature points with the same name within the unit achievement area (the statistical range can be appropriately expanded if difficult) to conduct error statistics in plane position. The registration errors of multispectral and panchromatic orthophoto were compared by the way of nested check, and whether the middle error and the maximum error met the accuracy requirements.

3.3 Logical Consistency

3.3.1 Verification Content: Check the correctness of the data file storage organization and data file format (extension); check whether the data file is missing, redundant and readable; check the correctness of file naming.

3.3.2 Technical Index Requirement: (1) Data content: The data content of the whole-scene correction image result consists of the whole-scene multi-spectral image file, whole-scene panchromatic image file, whole-scene RGB fusion image file, projection-information file recording image projection information and metadata file. The data content of 1:50000 standard framing digital ortho image consists of three parts: image file, image projection information file and metadata file. (2) Data format: Image files are in uncompressed standard GeoTIFF (.tif) format or Erdas Img (.img) format; Image files are stored in logical block structure with block size of 256*256 pixels (Tile is 256). The projection information file is in WKT format of OGC and saved in XML file format. Image projection information should also be stored inside the image file. The metadata is in xml format file (.xml). (3) File naming: digital orthophoto data result file naming rules to implement the overall production implementation plan requirements.

3.4 Time Accuracy

3.4.1 Verification Content: Check the current nature of the image.

3.4.2 Technical Index Requirement: The time phase requirements of original satellite remote sensing images required for coordinating satellite remote sensing image products are set to date, and the time nodes of each version of products have been described in the previous chapters.

3.5 Image Quality

3.5.1 Verification Content: Check the correctness of the ground resolution of the image; check the correctness of the initial coordinates of the image results; check the correctness of the expansion of the image results, the effective data range and the processing of special cases; check the correctness of the assignment of the non-data area of the image results; check whether the color mode and pixel bits meet the requirements; check the areas of uneven hue, obvious distortion and non-obvious contrast of the image. Check the color abnormality of image fusion processing; check whether there is texture blur on the ground; check whether there are large area noise, speckles and black and white spots in the image results; check whether the cloud cover meets the requirements; check whether there is a zero value in the gray level of the data coverage area of the whole scene RGB fusion image; check whether there is a color anomaly on the edge of the whole scene RGB fusion image. Check the blurred texture, noise, poor definition, blurred image, cracks, loopholes and other areas that can not read the image information or the degree of pixel loss caused by data processing.

3.5.2 Technical Index Requirement: (1) Resolution: the ground resolution setting of whole-scene panchromatic image and whole-scene RGB fusion image should be consistent with the resolution of panchromatic image after orthographic correction; The resolution setting of the full-scene multispectral image should be consistent with the resolution of the multispectral image after orthographic correction. (2) Data range: in principle, full-scene correction images should be produced. (3) Image cloud cover: in principle, the cloud cover should not exceed 20%. (4) Image features: the pixel number and band number of the whole panchromatic image should be consistent with the original satellite panchromatic image, and the pixel number and band number of the whole multispectral image should be consistent with the original multispectral image. The whole scene RGB fusion image is RGB color mode, single channel 8bit, RGB 3 channel 24 bit. After enhancement, the texture of the image should be clear, the expressive force of the object should be more obvious, there is no significant noise, and large spots or black and white spots are not allowed to cover the object, which will affect the visual interpretation effect of the object. Enhanced color image should be saturated color, natural bright, clear texture, moderate contrast. The fusion image should be rich in level, without the phenomenon of phantom and double image. With blue, green, red three bands of image color should be natural, close to true color. The gray level of the coverage area of the whole RGB fusion image data shall not be 0 value, and there shall not be abnormal edge color (black edge, false color, stain, stripe, etc.). The single surface object (such as forest, desert, mountain, etc.) of non-artificial surface due to topographic reasons does not need to be processed; Overpasses, viaducts and other deformation need not be treated.

3.6 Attachment Quality

3.6.1 Verification Content: Check the number of errors and omissions of metadata; check the number of errors and omissions of various contents of metadata; check the integrity of the subsidiary materials of the unit results; check the standardization of the subsidiary materials of the unit results.

3.6.2 Technical Index Requirement: Full-scene digital orthophoto forms a metadata file per scene.

4. PRODUCT QUALITY VERIFICATION

4.1 Experiment Design

In the experiment, 100 representative integrated satellite remote sensing image products are selected as verification samples, and the verification samples are investigated in detail, with location accuracy, cloud cover and image characteristics as the main statistical indexes. the research is carried out in the following aspects, and the distribution law of quality characteristics is analyzed combined with charts.

4.2 Result Analysis

4.2.1 Position Accuracy: According to different topographic and geomorphological features, two types of samples are selected: flat land and mountain area. The position accuracy is verified, and the accuracy characteristics of the product are analyzed and summarized.

All the samples were divided into two different landform, namely flat land and mountain land, and the product accuracy was verified respectively. By selecting the same name points of the integrated satellite remote sensing image and high-precision image, about 30 checkpoints were compared in each scene, and the poor checkpoint location was calculated, and then the error in the embedding was calculated to evaluate the accuracy of image correction. There are 50 scenes of mountainous/high mountain images and 48 scenes of flat/hilly images. The statistical convergence error of each scene is shown in the figure below.

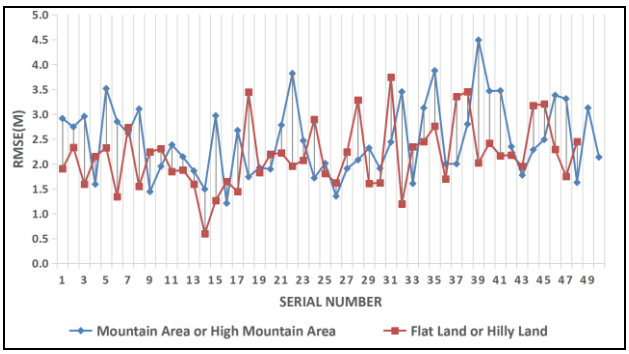

Figure 1. RMSE distribution in the image plane.

Terrain Types	Mean Value (m)	Maximum Value (m)
Flat Land or Hilly Land	2.2	3.7
Mountain Area or High Mountain Area	2.5	4.5

Table 3. Mean and maximum RMSE in image plane accuracy.

As can be seen from the table, the position accuracy of mountain/high mountain and flat/hilly land is basically the same, and the maximum error in embedding is 4.5m and 3.7m respectively, and the average error in embedding is 2.5m and 2.2m respectively.

4.2.2 Cloud Cover Analysis: According to different temporal characteristics, the time series samples of four quarters of the whole year are selected, the cloud cover is verified, and the seasonal quality characteristics of the products are analyzed and summarized.

All the samples were divided into four quarters according to the time phase, namely, the first quarter (January-March), the second quarter (April-June), the third quarter (July-September), and the fourth quarter (October-December), and the product cloud cover was analyzed respectively. Cloud coverage only considers thick cloud, thin cloud, mist, haze, cloud shadow and other conditions do not affect the interpretation of ground objects, and the cloud coverage area is not included.

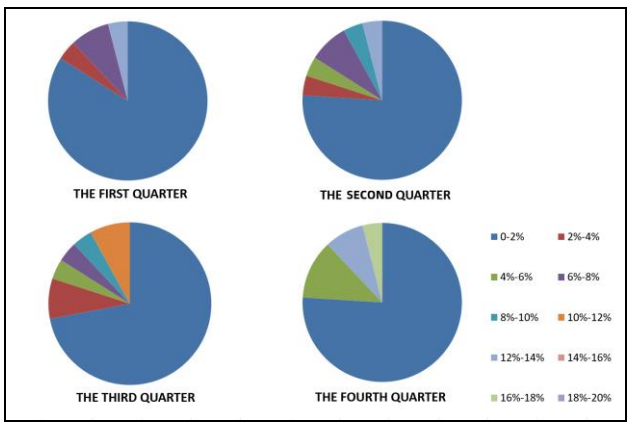

Figure 2. Analysis of cloud cover from the first to the fourth quarter.

As can be seen from the figure, the cloud coverage of more than 60% of the integrated satellite remote sensing images is between 0% and 2%. The cloud coverage of the third quarter was higher than that of the other three quarters, and the cloud coverage of the first quarter was the lowest, which was analyzed to be due to the greater influence of snow cover in winter.

4.2.3 Image Feature: According to different regional characteristics, samples from the eastern and western regions are selected to verify the image features, and the image quality characteristics of the products are analyzed and summarized.

All samples were divided into two different regions in the east and west, and the quality characteristics of each landscape image were evaluated respectively, including overexposure, color anomaly, color bias, color distortion, edge anomaly, shadow, color band difference, color spot, abnormal fringe, image blur, color overflow, color darkening, image loss, etc. Then count the number of each type of image quality problems. There are 52 images in the eastern region and 48 images in the western region. The quantity statistics of image quality problems are shown in the following table.

Quality Problem	Eastern region (Number, per-centage)	Western region (Number, per-centage)
Overexposure	21/52=40.4%	13/48=27.1%
Color Anomaly	11/52=21.2%	8/48=16.7%
Color Bias	4/52=7.7%	1/48=2.1%
Color Distortion	3/52=5.8%	1/48=2.1%
Edge Anomaly	7/52=13.5%	7/48=14.6%
Shadow	4/52=7.7%	3/48=6.6%
Color Banding Difference	6/52=11.5%	2/48=4.2%
Color Spot	2/52=3.9%	3/48=6.3%
Anomalous Fringe	4/52=7.7%	1/48=2.1%
Image Blur	1/52=1.9%	9/48=18.75%
Color Overflow	1/52=1.9%	0/48=0%
Darkening	3/52=5.8%	1/48=2.1%
Image Loss	1/52=1.9%	0/48=0%

Table 4. Image feature distribution in different regions.

As can be seen from the table, overexposure is the most frequent quality problem, followed by abnormal color and blurred image. The population density in the eastern region is higher, while the population density in the western region is lower. The main reason is that the overexposure caused by buildings is scattered in dots. Picture shows an example of a typical quality problem.

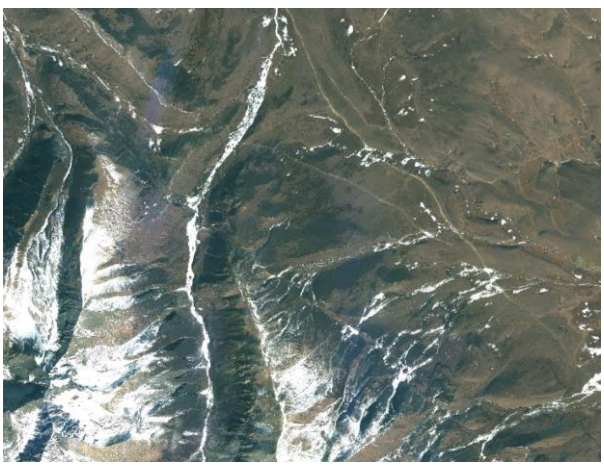

Figure 3. Abnormal color in fused image.

Figure 4. Mountain shadow in fused image.

Figure 5. Overexposure in fused image.

Figure 6. Abnormal stripes in fused image.

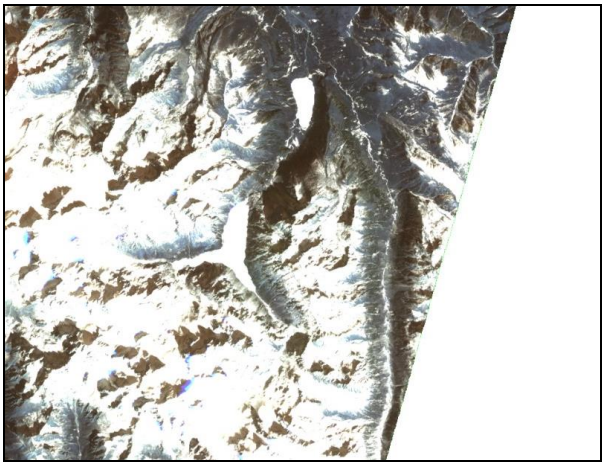

Figure 7. Fusion image edge anomalies and color overflow.

As shown in the figure, there are common quality issues with image features. Figure 3 shows abnormal color in the image, Figure 4 shows mountain shadows in the image, Figure 5 shows overexposure in the image, Figure 6 shows abnormal stripes in the image, and Figure 7 shows edge abnormalities and color overflow. Among them, there are issues such as overexposure and shadows caused by terrain and features themselves, color anomalies caused by original multispectral images, abnormal stripes and color overflow caused by snow cover, which cannot be dealt with in the data production process. These issues are all attributed to quality issues caused by the original image itself.

Due to the quality of the original image, through the selection of better original image to solve. When the original images that fully meet the technical requirements cannot be obtained, the data of cultivated land, garden land, forest land, grassland, business service, industrial and mining storage, housing, public management and public service, transportation, water area and water conservancy facilities should be selected as far as possible without shielding, so as to minimize the impact for the use.

4.2.4 Cause Analysis: Analyze the causes of the quality problems, and summarize the main problems from the two aspects of the original image itself and the data processing process.

To sum up, the above quality problems can be generally summarized into two categories: (1) original satellite image data problems, such as cloud, fog, shadow, noise, overexposure, etc.; (2) Problems caused by data processing, such as tone and blur, need to be improved in the production process.

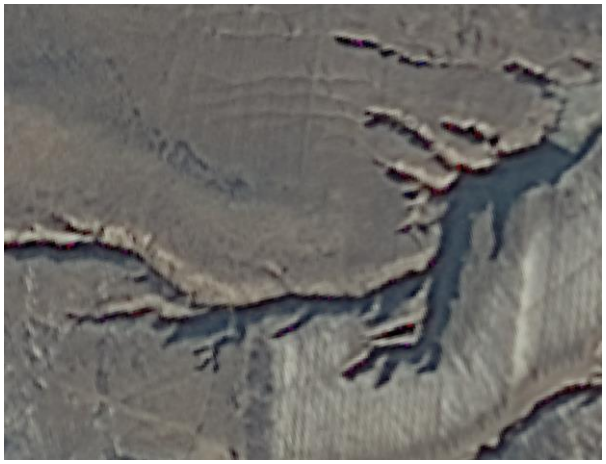

Figure 8. Anomaly pixels caused by data processing.

The pixel anomaly caused by data processing is shown in Figure 8, mainly distributed in the shaded area of the mountain, with a size of one pixel and a scattered distribution. Although the area is small, the overall quality of the image needs to be corrected.

5. CONCLUSION

In this paper, based on the characteristics of the production work of the 3D China Construction special coordinated satellite remote sensing image and the tasks in 2022, according to the technical index requirements of the project and relevant standards and specifications, make full use of the production data and high-precision reference data, and comprehensively adopt the methods of data review, high-precision data comparison, human-computer interaction check and software automatic check to verify the quality of the product. It provides an important reference for the quality evaluation of real-3D special products in China construction.

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