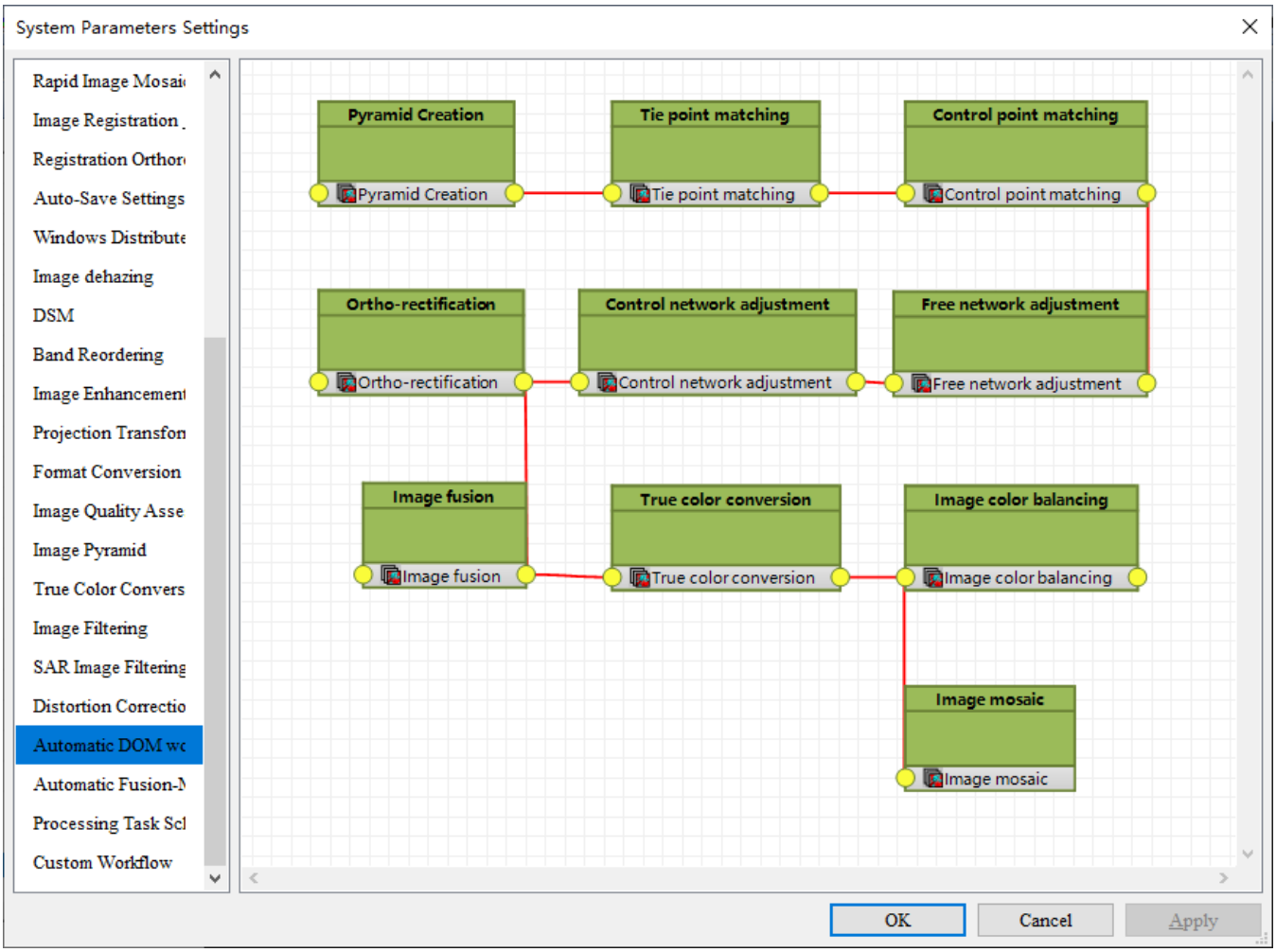
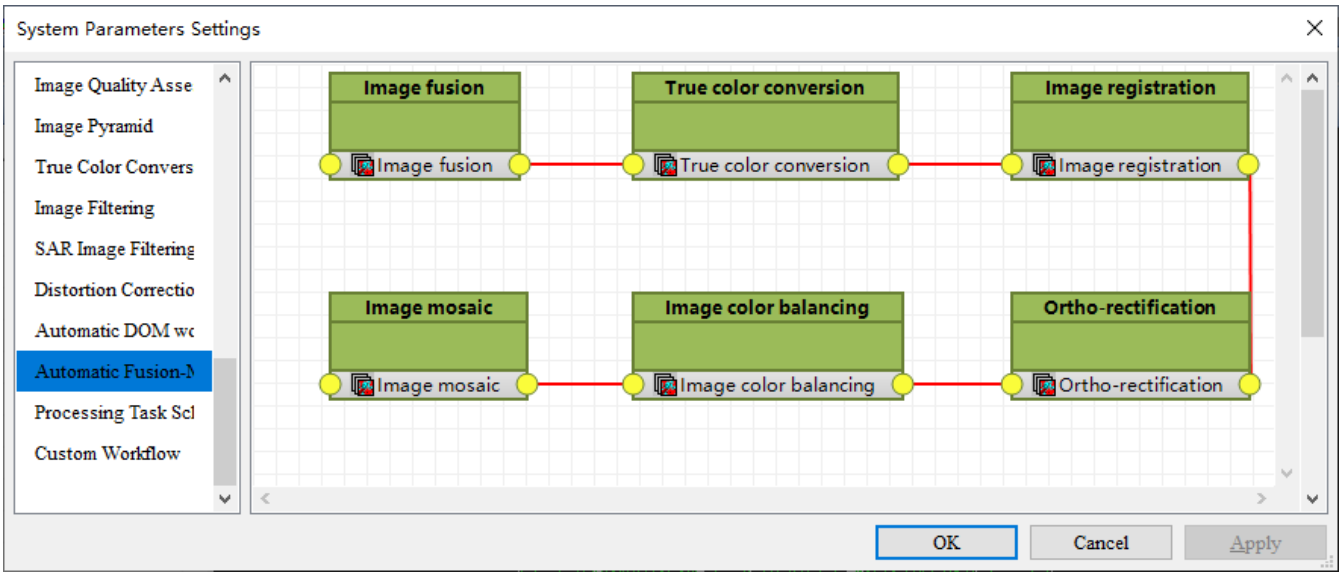
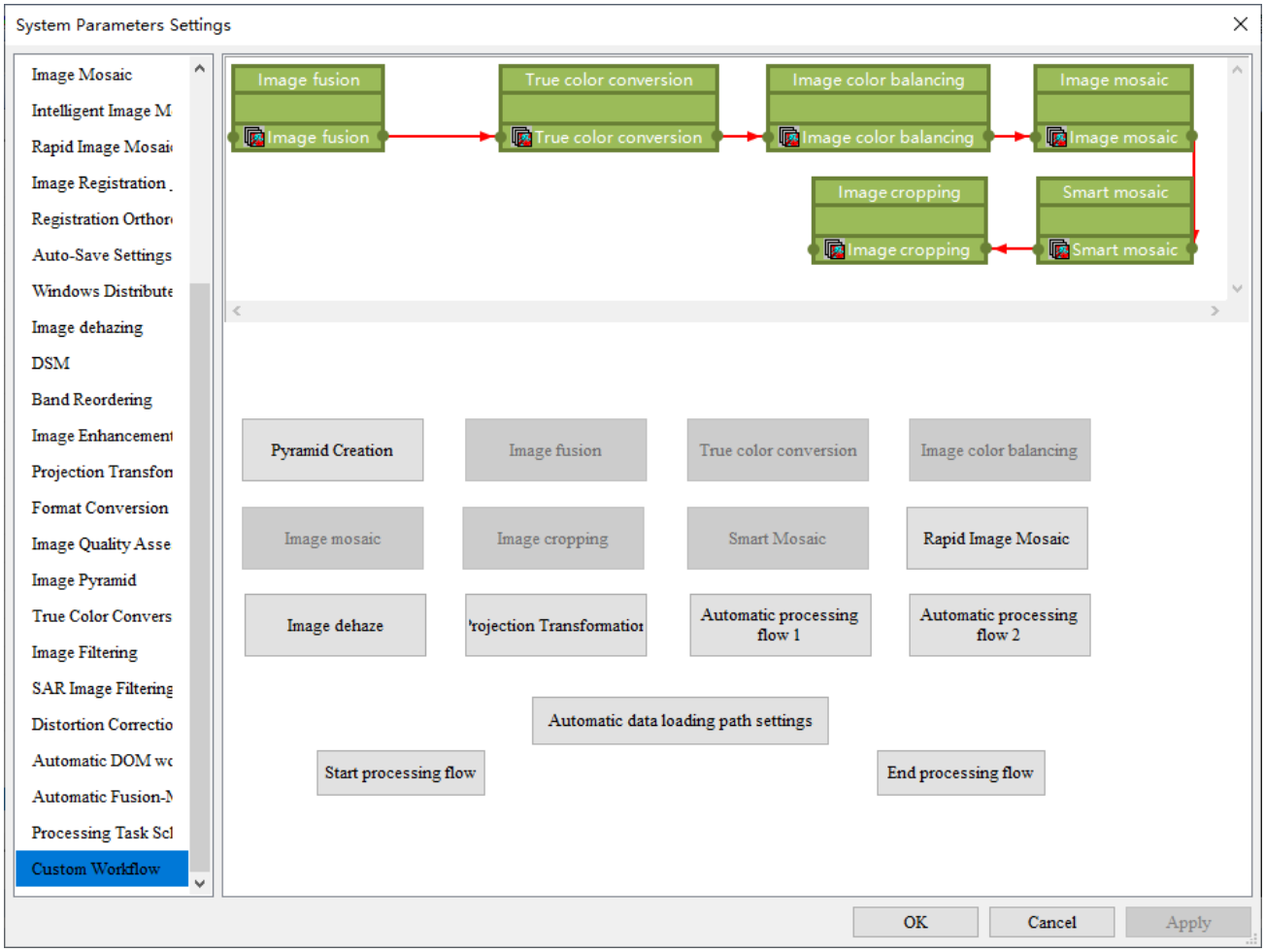
Key Features and Highlights of SVP Software

1. One-click, automated production workflow for both optical and radar imagery

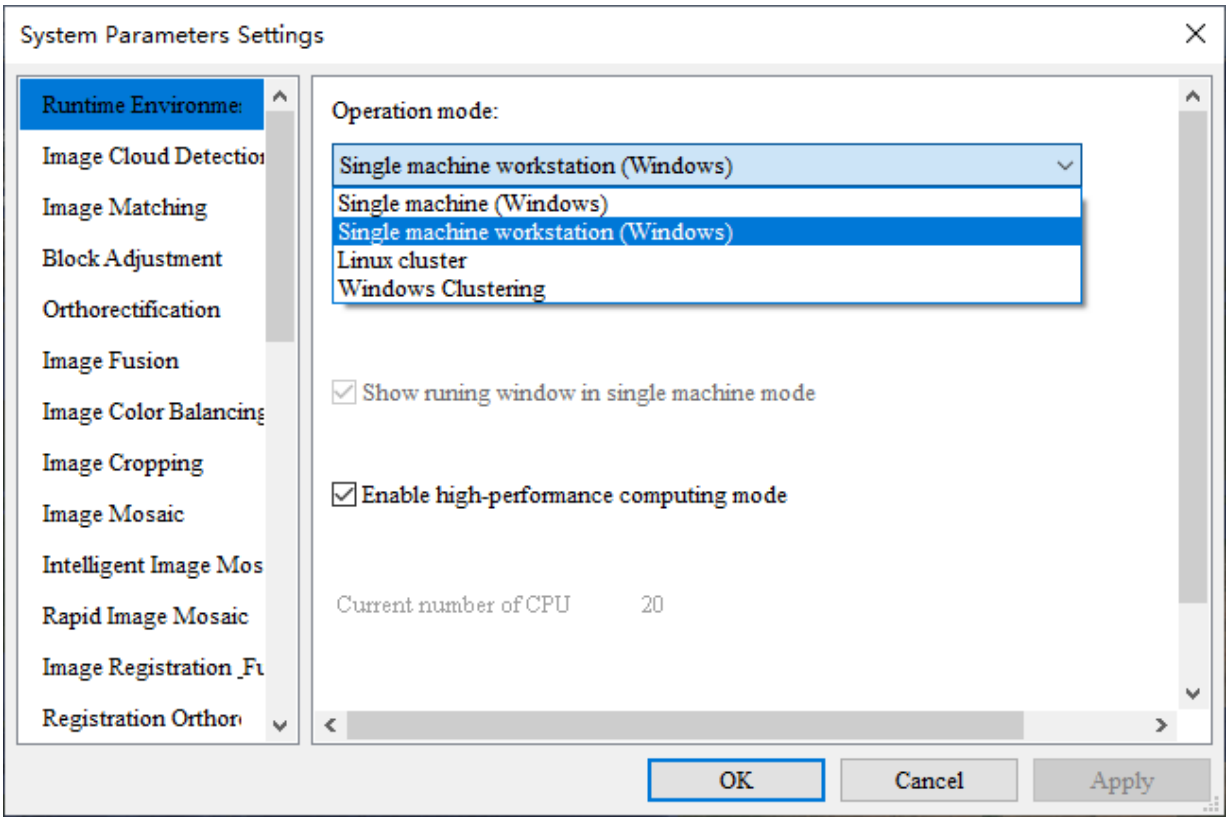
SpaceVoxelProcessor (SVP) provides different automatic production workflows including automatic DOM productions workflow， automatic fusion-mosaic workflow and custom workflow, users can select the appropriate automated workflow for image processing based on practical image production requirements.

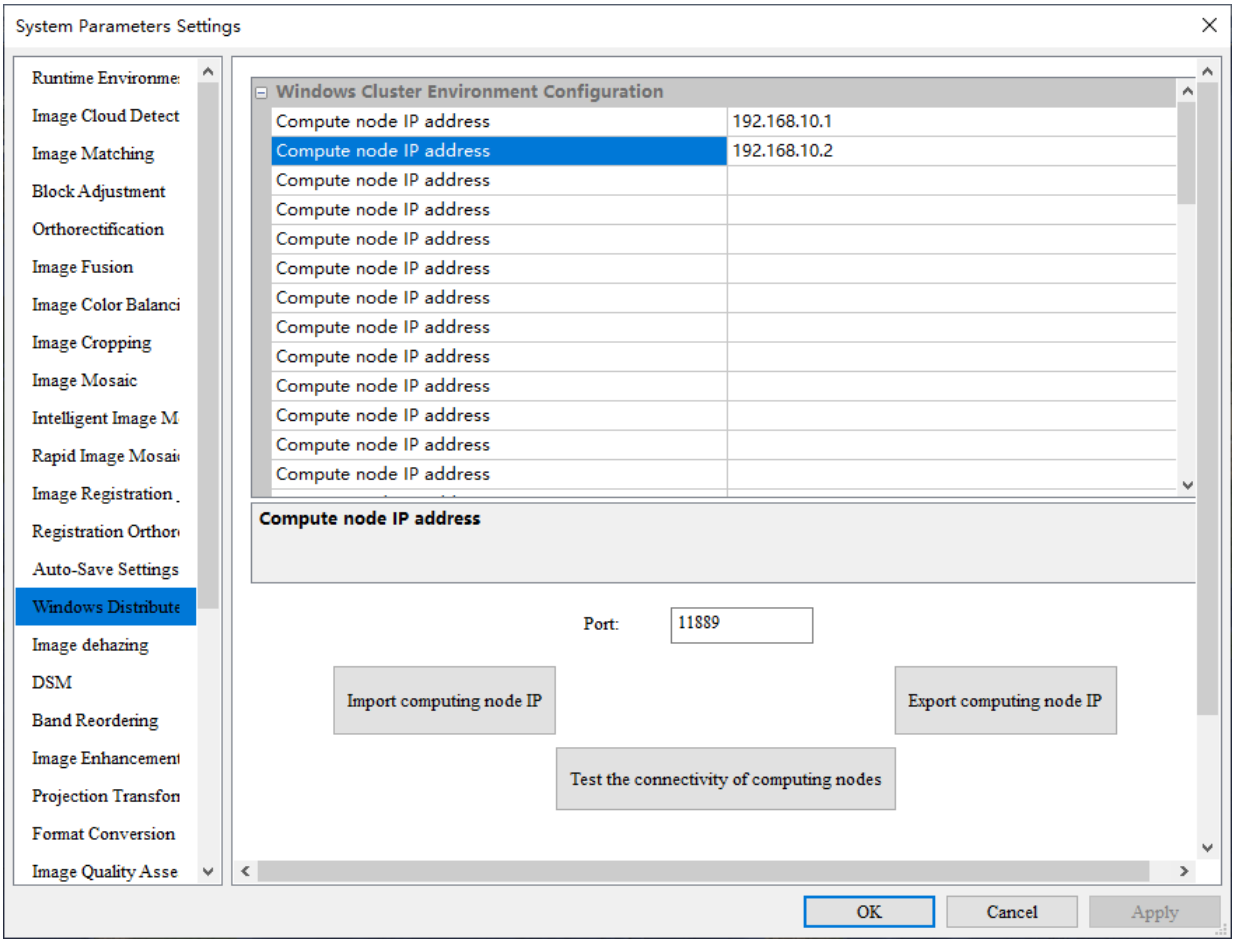






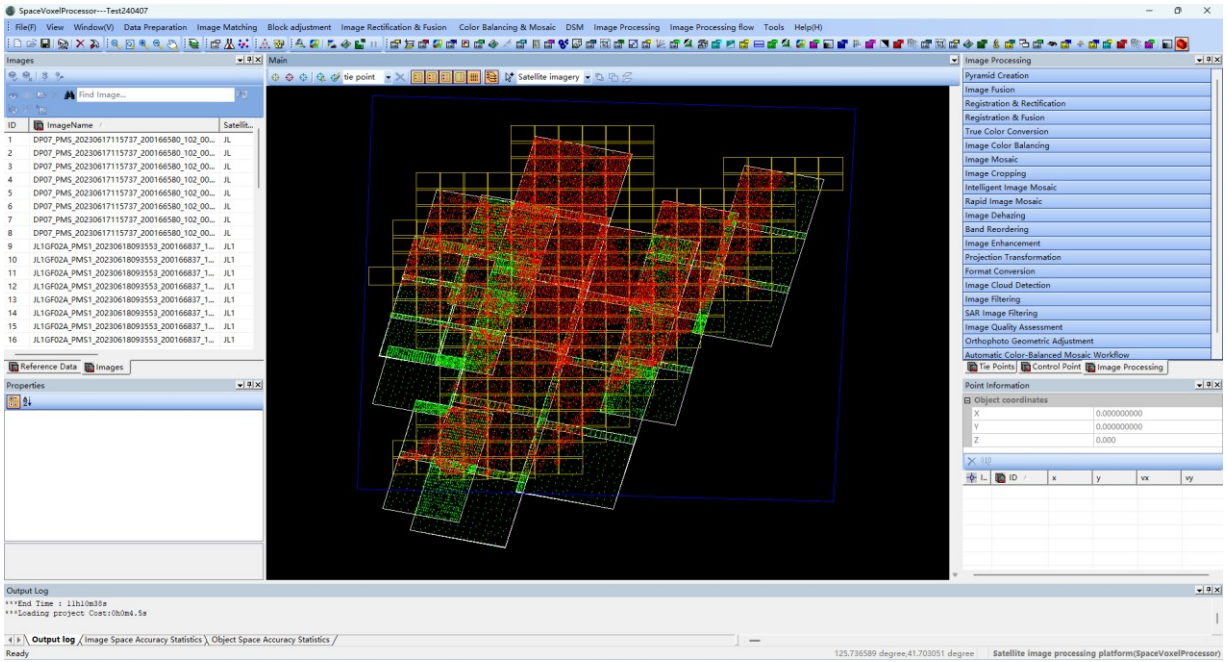
2. Supports both standalone computing and computer cluster computing processing modes





3. Automatic Block Adjustment Processing

SVP provides a fast and high-precision image matching algorithm that can realize fully automatic matching between images under difficult conditions such as multi-source, multi-phase, rotational distortion, etc.; at the same time, it adopts a variety of gross error elimination methods to completely and automatically eliminate error points, and the matching accuracy can reach sub-pixel level.



3.1 Rare control of large-scale block adjustment technology

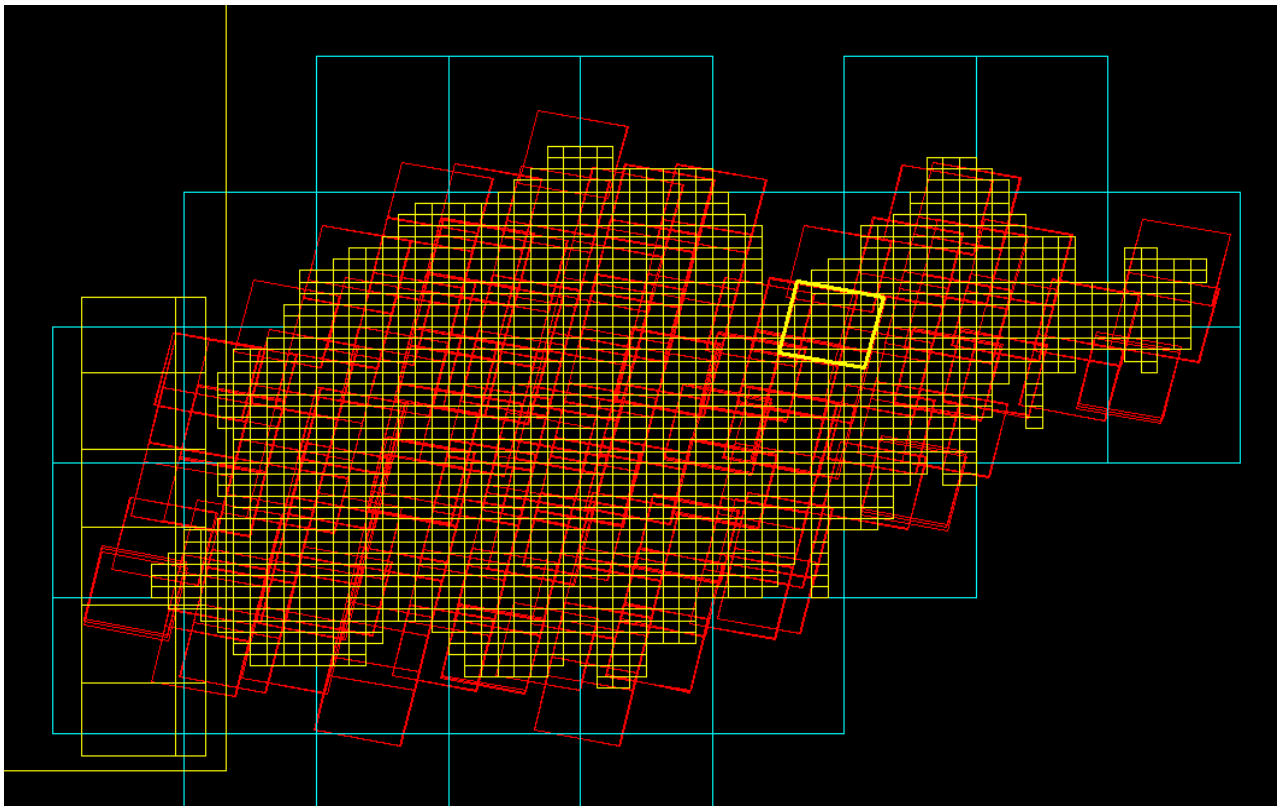
The adjustment technology based on adaptive weighting and virtual observation constraints, as well as the automatic detection technology for pathological areas, achieves spatial adjustment processing of multi-source satellite images under sparse multi-source ground control conditions by matching tie points and using a small number of ground control points.

The method reliably and automatically extracts well-distributed image tie points and integrates the well-known "alternate approach" from photogrammetry with a global least-squares adjustment algorithm to achieve integrated block adjustment for large-area satellite imagery. Essentially, this is equivalent to constructing virtual "mean" control points for block adjustment, which not only resolves the rank deficiency issue in uncontrolled adjustment but also facilitates qualitative orientation analysis of the adjustment results.

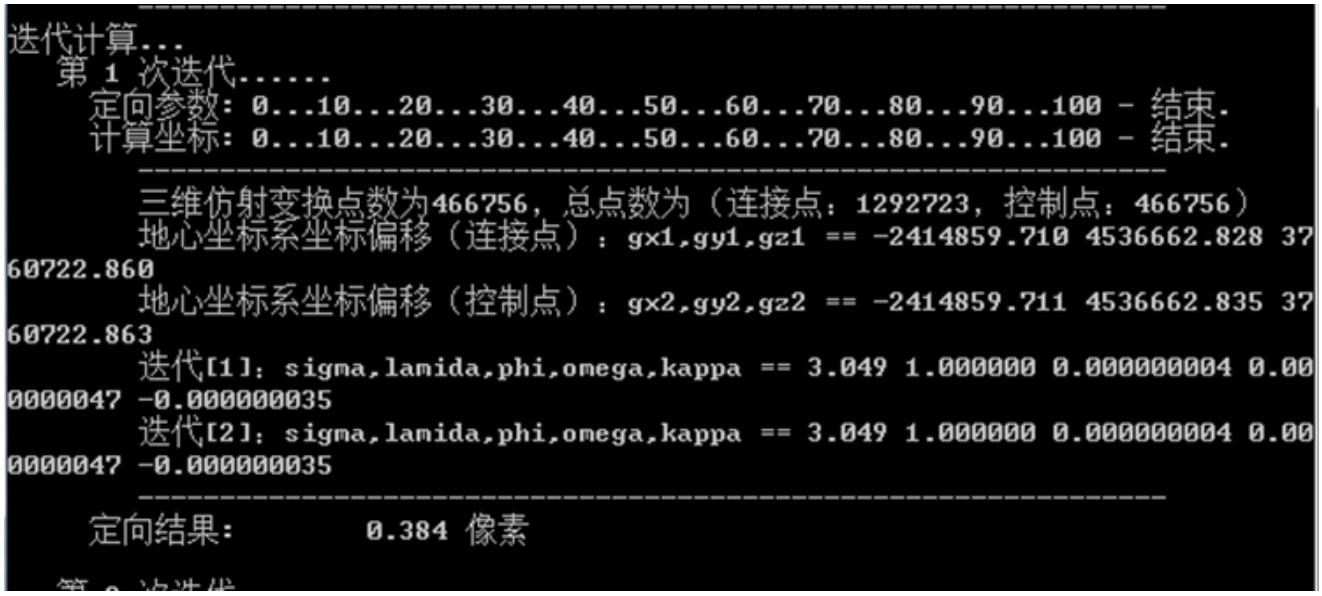
Furthermore, to address practical challenges in surveying and mapping production—such as seamline mismatches between different regions—the adjustment model incorporates third-party geospatial data as planar and elevation geometric constraints. This helps minimize residual error accumulation during the global adjustment process, thereby yielding more reliable and "unbiased" block adjustment results.

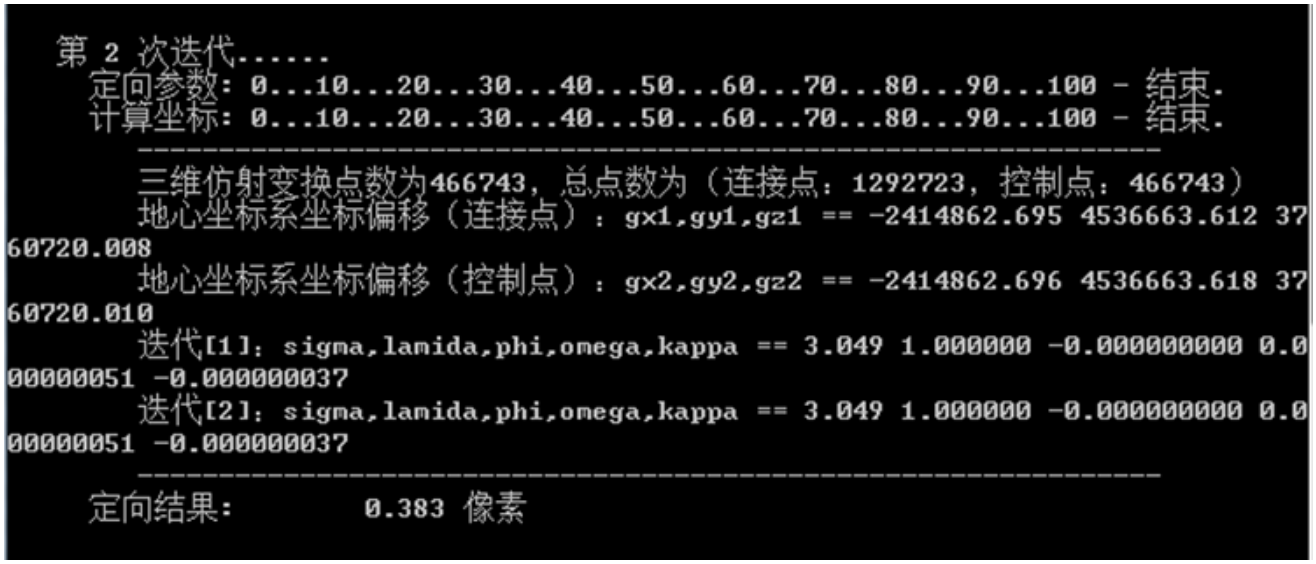
Case 1：

- **Images from Tianhui Satellite, Total 152 image models which cover the whole province.**
- **Reference Data: 30m SRTM and 5m Google satellite images**



- Use the block adjustment results to analyze whether adjacent images edge mismatches (edge mean error exceeding 3.5 pixels) or vertical parallax (image-space mean error exceeding 1.5 pixels).
- Following orthorectification, verify the edge alignment between adjacent images and their registration with the base map to confirm the problematic images identified in the block adjustment analysis. The inspection revealed that three images had initial offsets exceeding 600 pixels.
- The final adjustment mean error was 0.383 pixels, meeting practical production requirements."

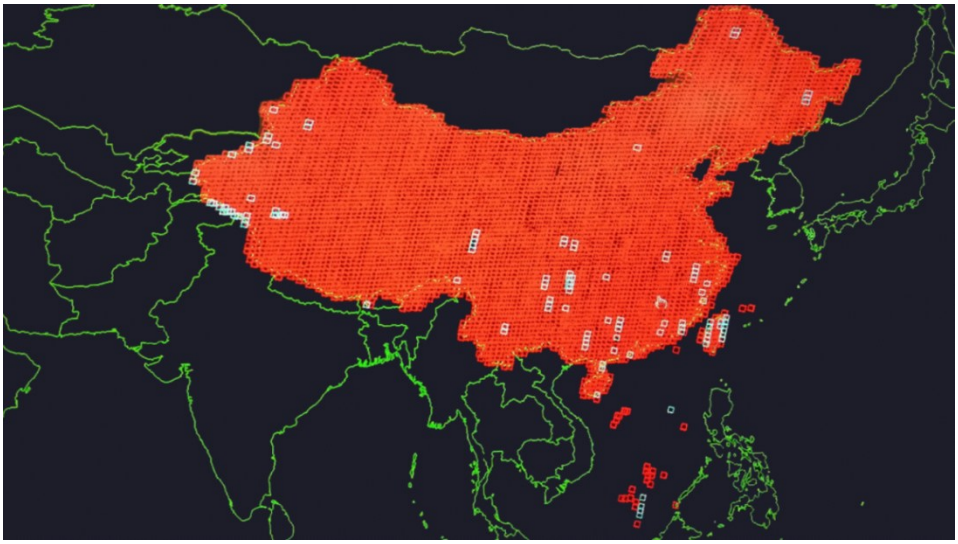




Case 2：

- **7321 scenes of standard image from Ziyuan 3 satellite(including forward, nadir and backward) , total 20,756 images ,were acquired, covering an area of 9.55 million km²,**

accounting for 99.4% of the country's total territory.



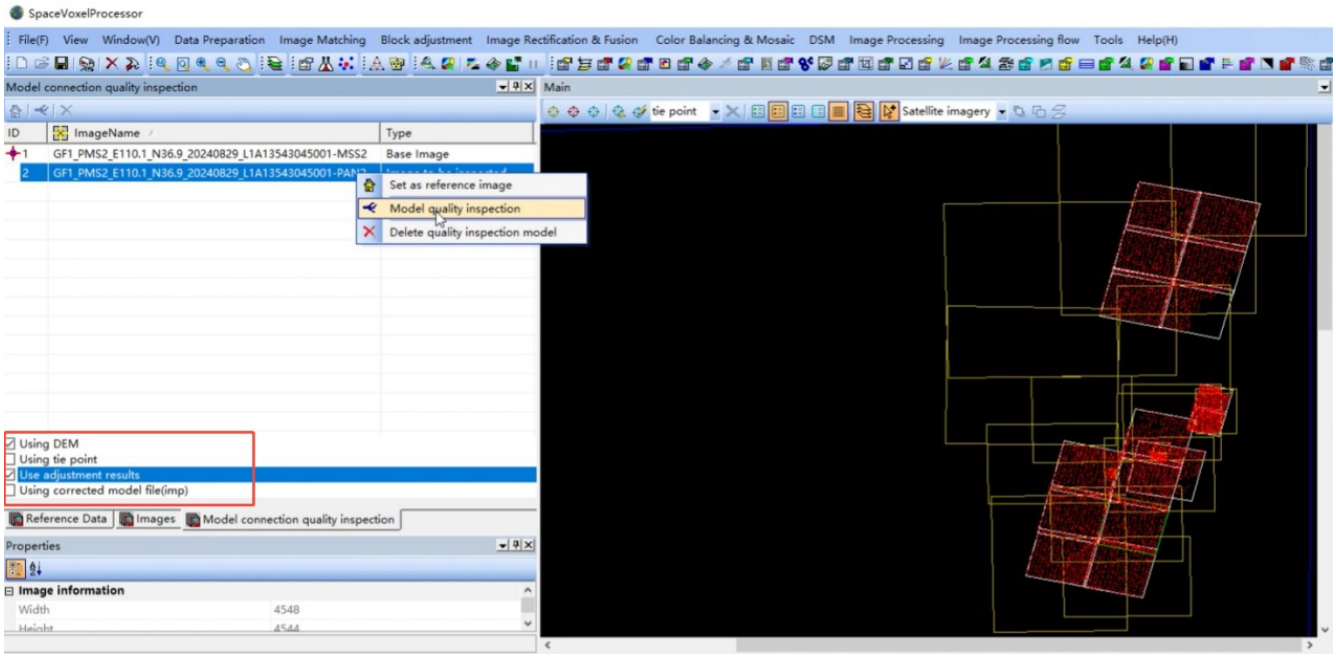
The block adjustment was processed in a cluster computing environment, achieving an orientation mean error of 0.548 pixels.

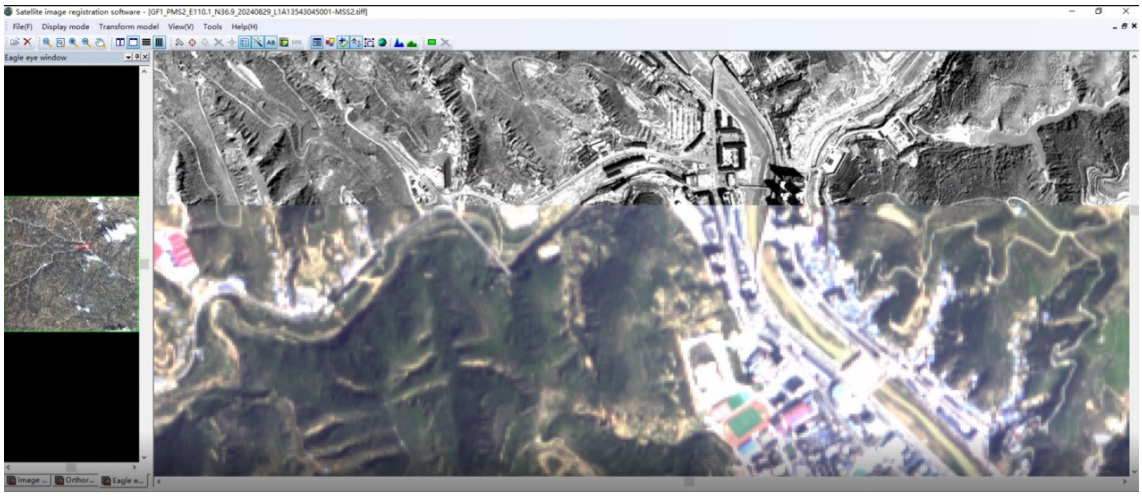
The total number of tie points reached 31,311,860, with 14,063,576 reference control points employed. Verification using partial 1:50,000 scale data confirmed that the uncontrolled adjustment accuracy was better than 6 meters.

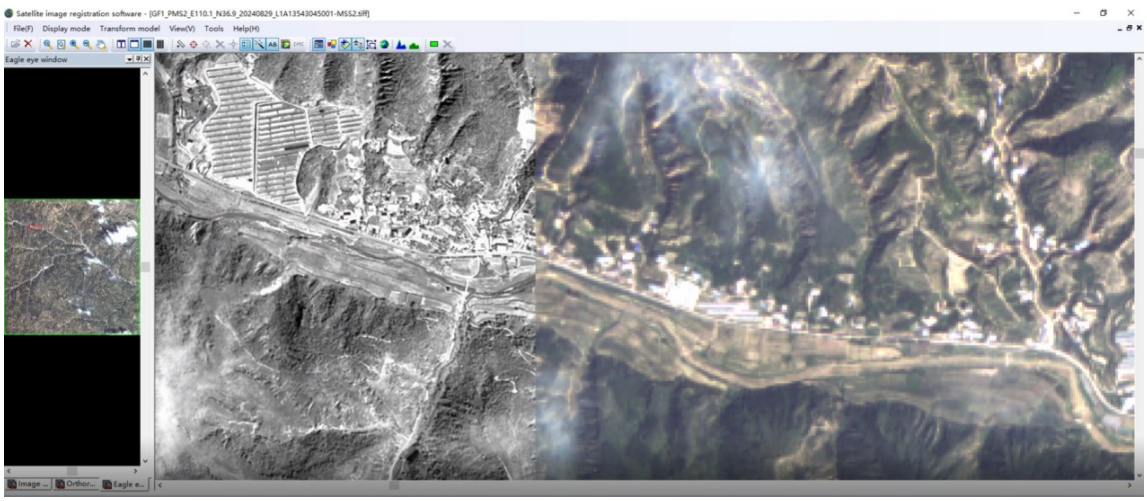
```
第 8 次迭代.....
  定向参数: 0...10...20...30...40...50...60...70...80...90...100 - 结束.
  计算坐标: 0...10...20...30...40...50...60...70...80...90...100 - 结束.
    ------------------------------------------------------------
    三维仿射变换点数为14063576，总点数为（连接点：31311860，控制点：14063576）
    地心坐标系坐标偏移（连接点）：gx1,gy1,gz1 == -1036577.371 4884105.159 3709854.700
    地心坐标系坐标偏移（控制点）：gx2,gy2,gz2 == -1036577.370 4884105.155 3709854.701
    迭代[1]：sigma,lamida,phi,omega,kappa == 3.667 1.000000 -0.000000004 0.000000012 0.000000018
    迭代[2]：sigma,lamida,phi,omega,kappa == 3.638 1.000000 -0.000000003 0.000000011 0.000000017
    迭代[3]：sigma,lamida,phi,omega,kappa == 3.635 1.000000 -0.000000003 0.000000011 0.000000017
    ------------------------------------------------------------
  定向结果:         0.565 像素

第 9 次迭代.....
  定向参数: 0...10...20...30...40...50...60...70...80...90...100 - 结束.
  计算坐标: 0...10...20...30...40...50...60...70...80...90...100 - 结束.
    ------------------------------------------------------------
    三维仿射变换点数为14063576，总点数为（连接点：31311860，控制点：14063576）
    地心坐标系坐标偏移（连接点）：gx1,gy1,gz1 == -1036577.369 4884105.156 3709854.699
    地心坐标系坐标偏移（控制点）：gx2,gy2,gz2 == -1036577.370 4884105.155 3709854.701
    迭代[1]：sigma,lamida,phi,omega,kappa == 3.646 1.000000 -0.000000004 0.000000012 0.000000014
    迭代[2]：sigma,lamida,phi,omega,kappa == 3.620 1.000000 -0.000000003 0.000000011 0.000000014
    迭代[3]：sigma,lamida,phi,omega,kappa == 3.617 1.000000 -0.000000003 0.000000010 0.000000014
    ------------------------------------------------------------
  定向结果:         0.555 像素

第 10 次迭代.....
  定向参数: 0...10...20...30...40...50...60...70...80...90...100 - 结束.
  计算坐标: 0...10...20...30...40...50...60...70...80...90...100 - 结束.
    ------------------------------------------------------------
    三维仿射变换点数为14063576，总点数为（连接点：31311860，控制点：14063576）
    地心坐标系坐标偏移（连接点）：gx1,gy1,gz1 == -1036577.368 4884105.154 3709854.699
    地心坐标系坐标偏移（控制点）：gx2,gy2,gz2 == -1036577.370 4884105.155 3709854.701
    迭代[1]：sigma,lamida,phi,omega,kappa == 3.632 1.000000 -0.000000004 0.000000011 0.000000011
    迭代[2]：sigma,lamida,phi,omega,kappa == 3.607 1.000000 -0.000000003 0.000000010 0.000000011
    迭代[3]：sigma,lamida,phi,omega,kappa == 3.604 1.000000 -0.000000003 0.000000010 0.000000011
    ------------------------------------------------------------
  定向结果:         0.548 像素

一共有 127 个模型定向结果出错（控制点/连接点为0、RPC参数问题等原因），已经被排除在平差计算之外
  模型 [11444320 - 11653829 - 11653830] 定向结果有问题，（剔除粗差后）模型内既无连接点也无控制点！！
  模型 [11444321 - 11653831 - 11653832] 定向结果有问题，（剔除粗差后）模型内既无连接点也无控制点！！
  模型 [11578827 - 11653853 - 11653854] 定向结果有问题，（剔除粗差后）模型内既无连接点也无控制点！！
  模型 [10650071 - 11666845 - 11666846] 定向结果有问题，（剔除粗差后）模型内既无连接点也无控制点！！
  模型 [10678260 - 11666883 - 11666884] 定向结果有问题，（剔除粗差后）模型内既无连接点也无控制点！！
  模型 [10699484 - 13072818 - 13072819] 定向结果有问题，（剔除粗差后）模型内既无连接点也无控制点！！
  模型 [10699482 - 13072822 - 13072823] 定向结果有问题，（剔除粗差后）模型内既无连接点也无控制点！！
```

3.2 Real-time Verification of Block Adjustment Accuracy

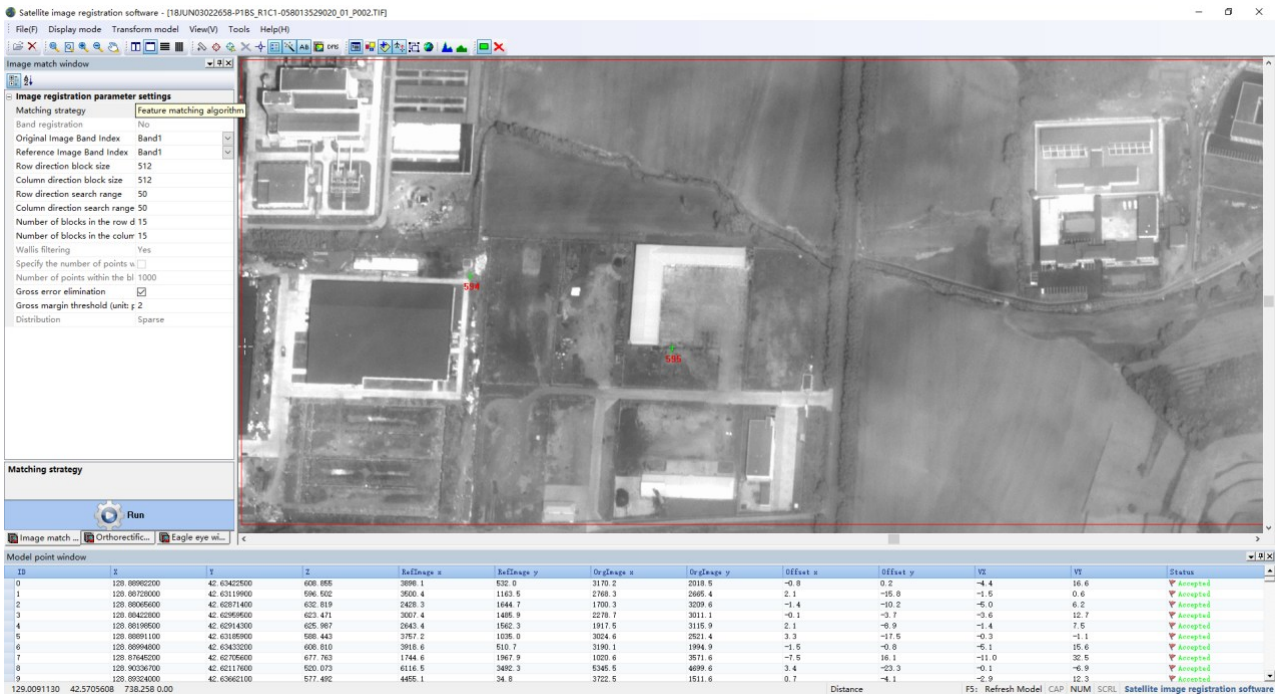
SVP software also provides simple and rapid visualization tools besides error statistics reports. These tools support swipe comparison of image rectification results based on DEMs, tie points, bundle adjustment results, or the corrected model, thereby enabling verification of whether the bundle adjustment accuracy meets requirements.







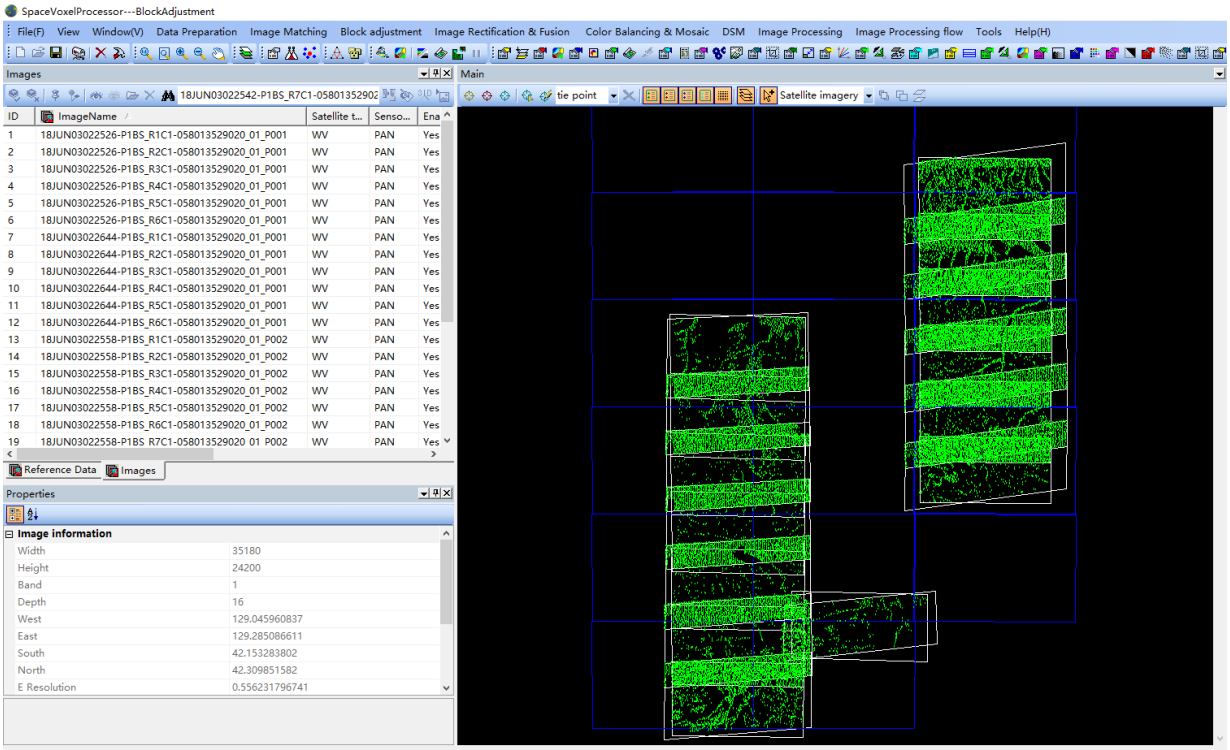
Additionally, users can select regions by drawing a bounding box to do automatic tie points again for areas with poor automatic tie-point matching.



3.3 Supports Different Level of Remote Sensing Images

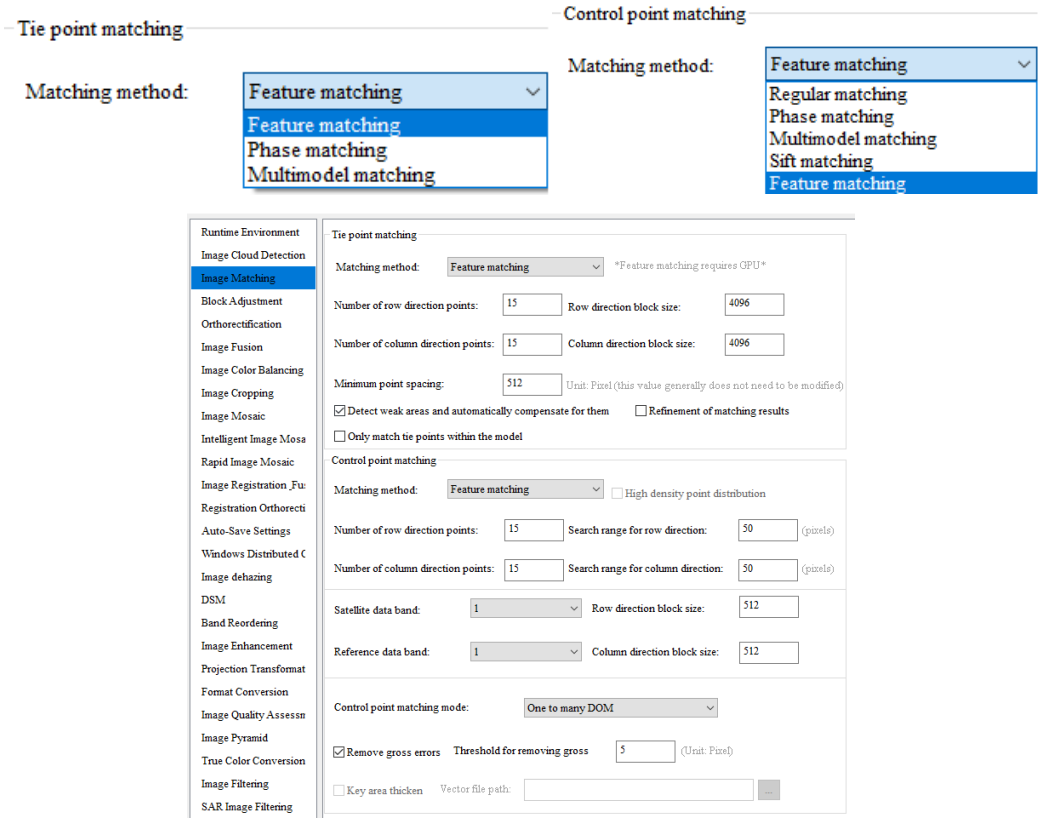
There are different levels of remote sensing images such as Level 1A, Level 2A and Level1B，etc. SVP software supports block adjustment processing for both Level A and Level B remote sensing images, whereas most other software does not support it for Level B images.

```
▼<isd>
  ▼<IMD>
      <VERSION>28.3</VERSION>
      <GENERATIONTIME>2018-06-22T15:17:12.000000Z</GENERATIONTIME>
      <PRODUCTORDERID>058013529020_01_P001</PRODUCTORDERID>
      <PRODUCTCATALOGID>A03001038A017B00</PRODUCTCATALOGID>
      <CHILDCATALOGID>210001038A017C00</CHILDCATALOGID>
      <IMAGEDESCRIPTOR>Stereo1B</IMAGEDESCRIPTOR>
      <BANDID>MS1</BANDID>
      <PANSHARPENALGORITHM>None</PANSHARPENALGORITHM>
      <NUMROWS>5461</NUMROWS>
      <NUMCOLUMNS>8820</NUMCOLUMNS>
      <PRODUCTLEVEL>Stereo 1B</PRODUCTLEVEL>
      <PRODUCTTYPE>Stereo</PRODUCTTYPE>
      <NUMBEROFLOOKS>2</NUMBEROFLOOKS>
      <RADIOMETRICLEVEL>Corrected</RADIOMETRICLEVEL>
      <BITSPERPIXEL>16</BITSPERPIXEL>
      <COMPRESSIONTYPE>None</COMPRESSIONTYPE>
      <OUTPUTFORMAT>GeoTIFF</OUTPUTFORMAT>
```



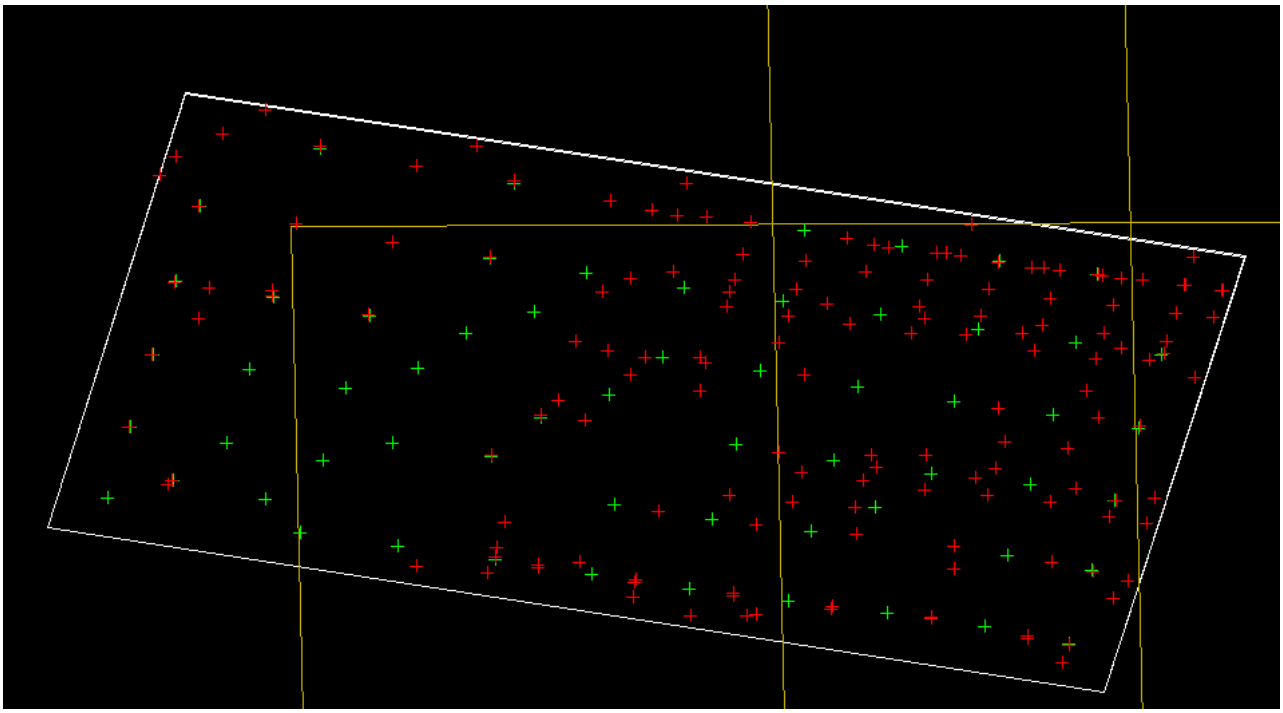
3.4 Integrates Different Auto Tie Points/Control Points Matching Methods

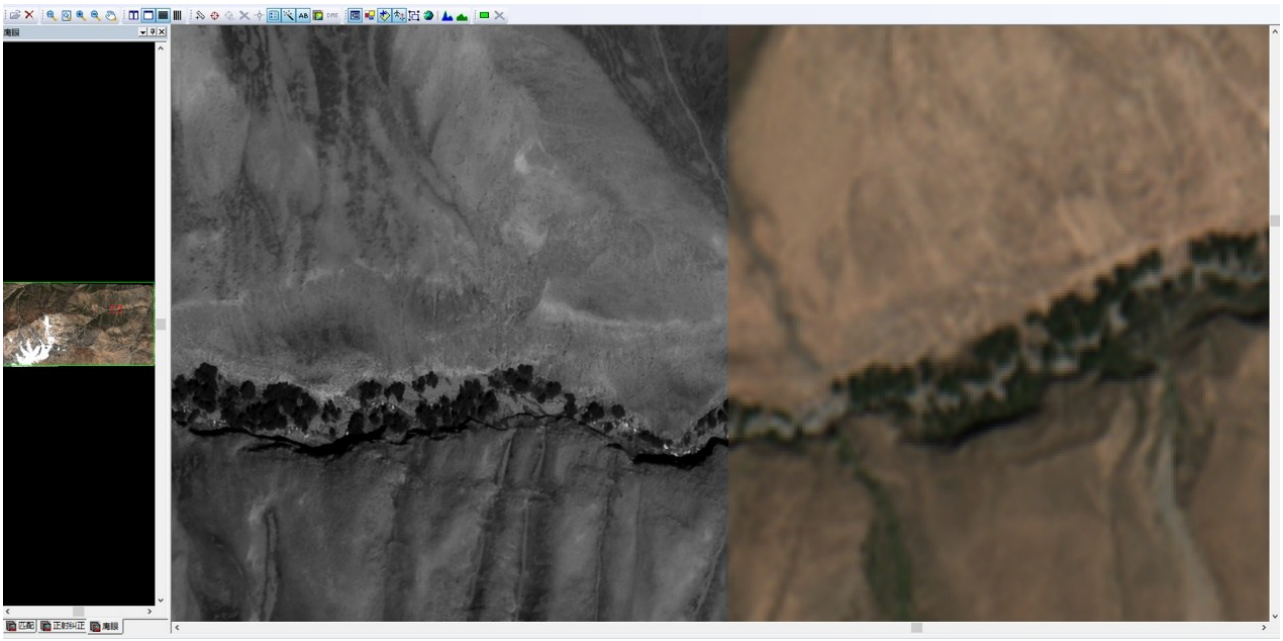
SVP software provides three different tie points methods: feature matching, phase matching and SAR phase matching, and five different control points matching methods: regular matching, feature matching, phase matching and SAR phase matching and SIFT matching.



Feature matching is the most commonly used method for tie point and control point matching. However, for weak-textured areas like forests and deserts, where there may be a significant

temporal gap between the reference image and the image to be processed, phase matching can be employed to yield higher-quality tie points and control points.

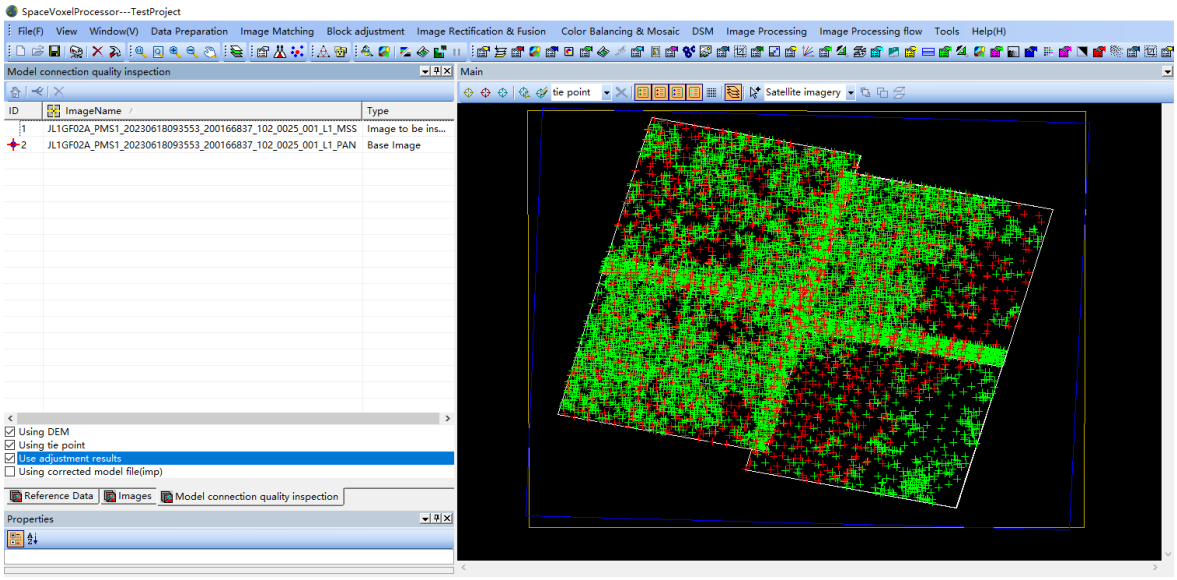


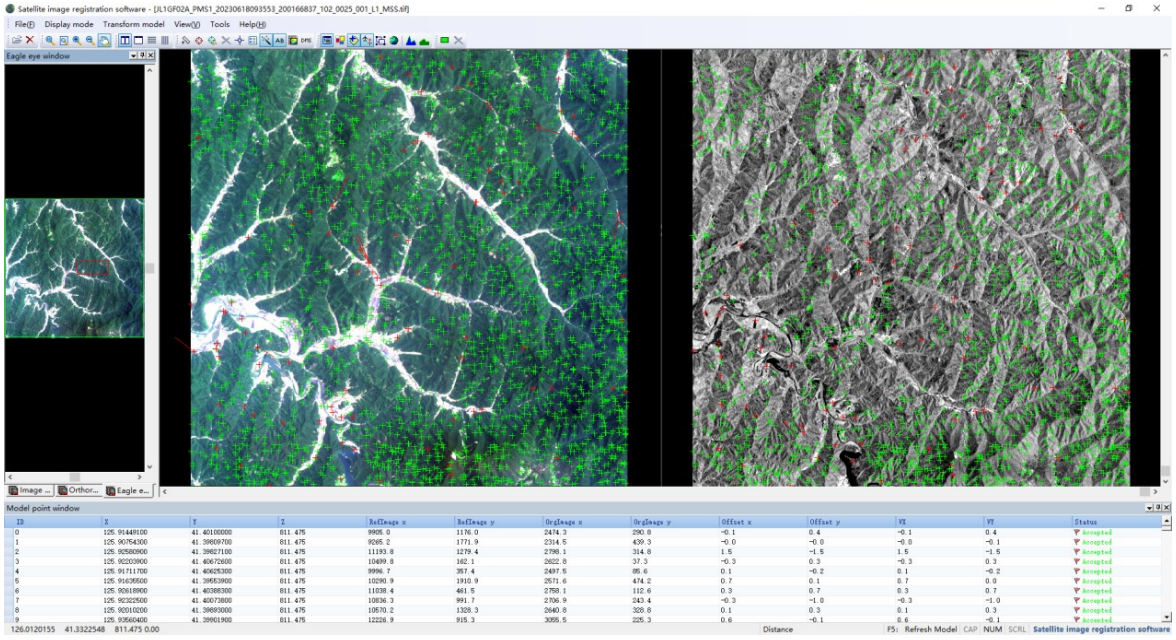


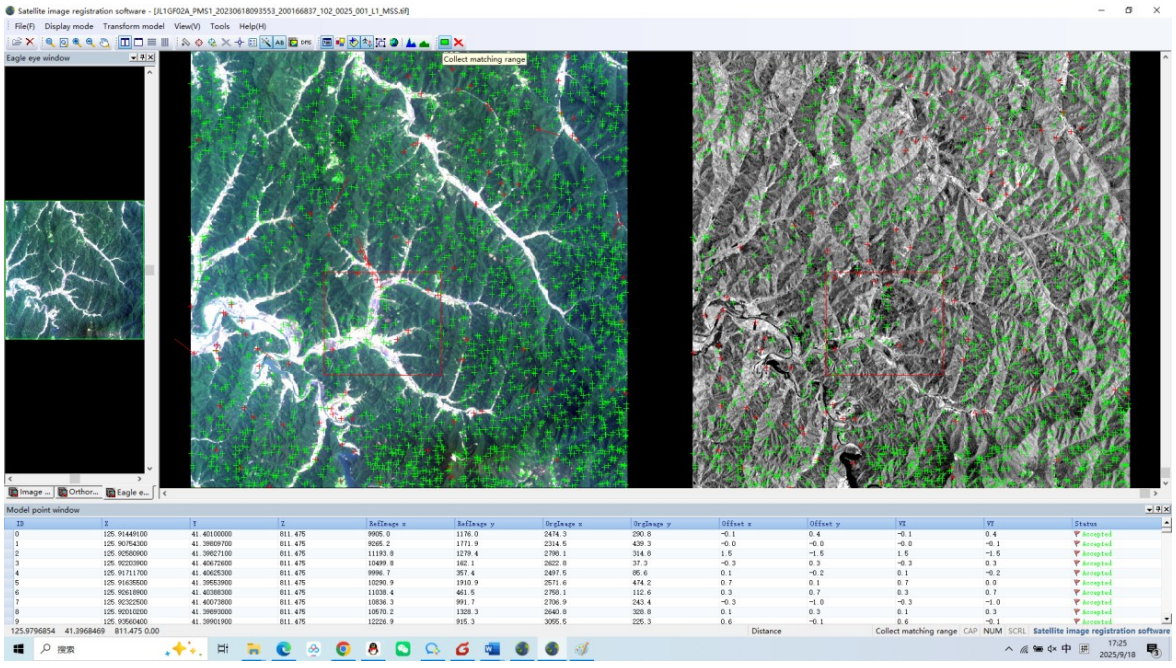
4. Image Rectification

4.1 View rectification results based on DEMs, tie points, bundle adjustment results, or the corrected model

SVP supports instant viewing of image rectification results through a swipe mode based on DEMs, tie points, bundle adjustment results, or the corrected model. Unlike other software that requires completing the rectification processing before allowing users to view the image rectification results.

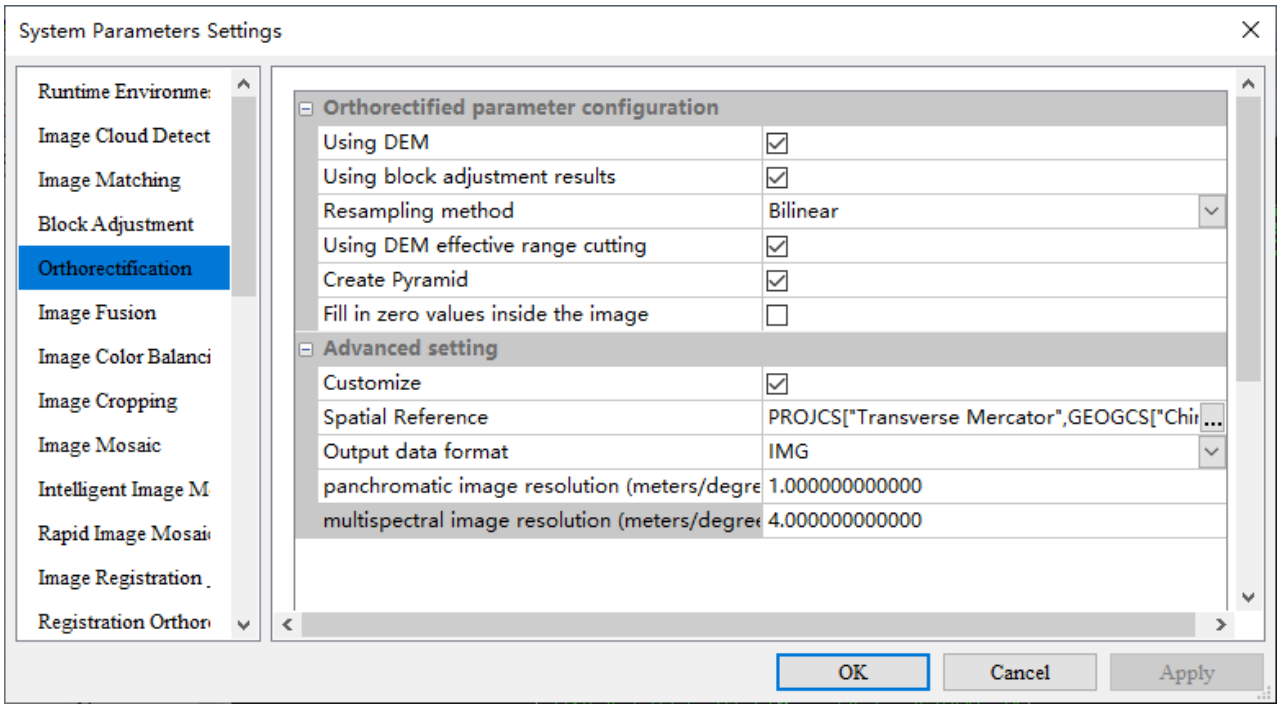

SpaceVoxelProcessor---TestProject
File(F) View Window(V) Data Preparation Image Matching Block adjustment Image Rectification & Fusion Color Balancing & Mosaic DSM Image Processing Image Processing flow Tools Help(H)
Model connection quality inspection
ID ImageName Type
1 JL1GF02A_PMS1_20230618093553_200166837_102_0025_001_L1_MSS Image to be ins...
2 JL1GF02A_PMS1_20230618093553_200166837_102_0025_001_L1_PAN Base Image
Using DEM
Using tie point
Use adjustment results
Using corrected model file(imp)
Reference Data
Images
Model connection quality inspection
Properties
Main
tie point
Satellite imagery


Satellite image registration software - [JL1GF02A_PMS1_20230618093553_200166837_102_0025_001_L1_MSS.tif]
File(F) Display mode Transform model View(V) Tools Help(H)
Eagle eye window
Model point window

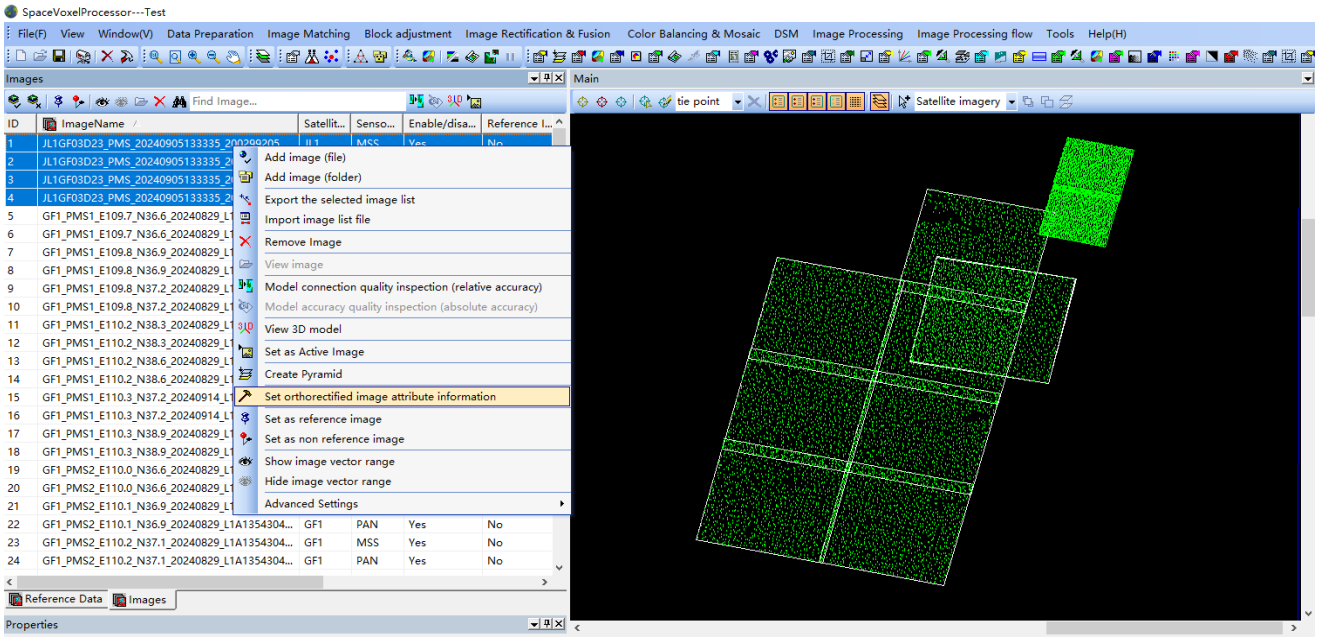

Satellite image registration software - [JL1GF02A_PMS1_20230618093553_200166837_102_0025_001_L1_MSS.tif]
File(F) Display mode Transform model View(V) Tools Help(H)
Eagle eye window
Collect matching range
Model point window

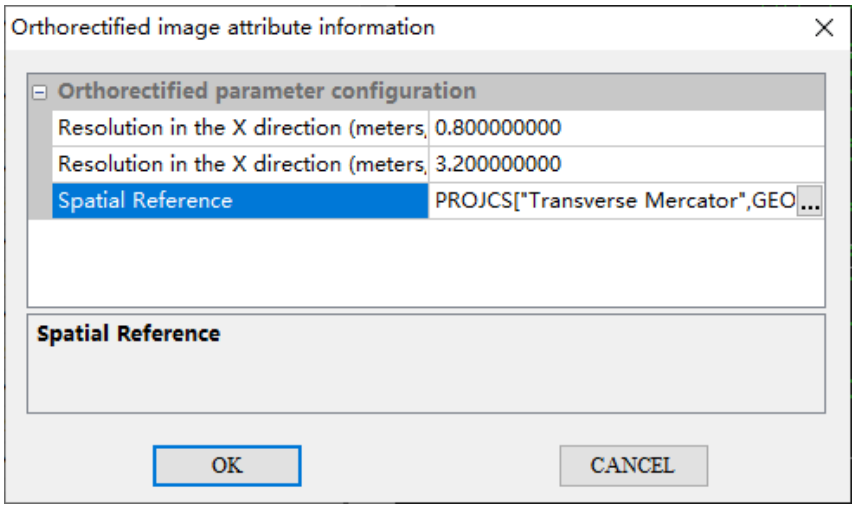
4.2 Set different resolutions for images with different resolutions when rectification processing is done together

During remote sensing image rectification, users often encounter situations where the images to be processed come from the same satellite source or different satellite sources. If the images to be processed have the same resolution (i.e., identical panchromatic image resolution and identical multispectral image resolution), the resolution of the rectified output can be uniformly set.



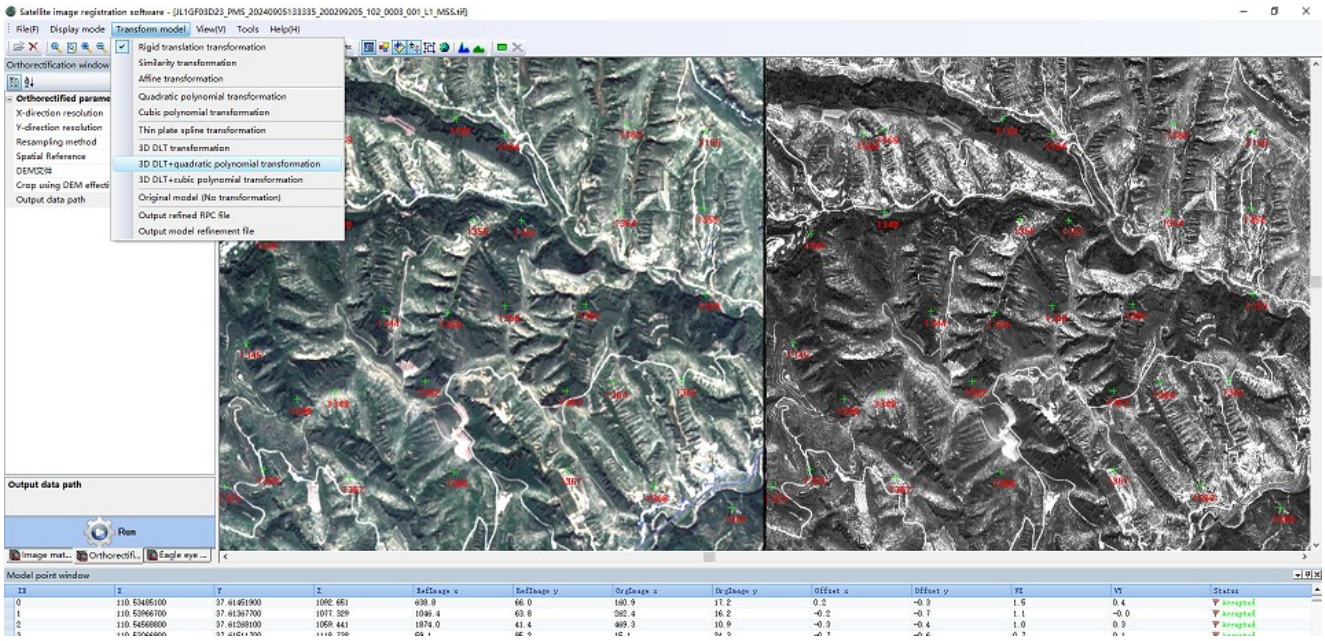
However, if the images to be processed have different resolutions (different panchromatic image resolution and different multispectral image resolution), most software systems cannot support setting different output resolutions for the rectification results. In contrast, SVP system allows users to set the resolution of the rectified output based on the varying resolutions of the input images.



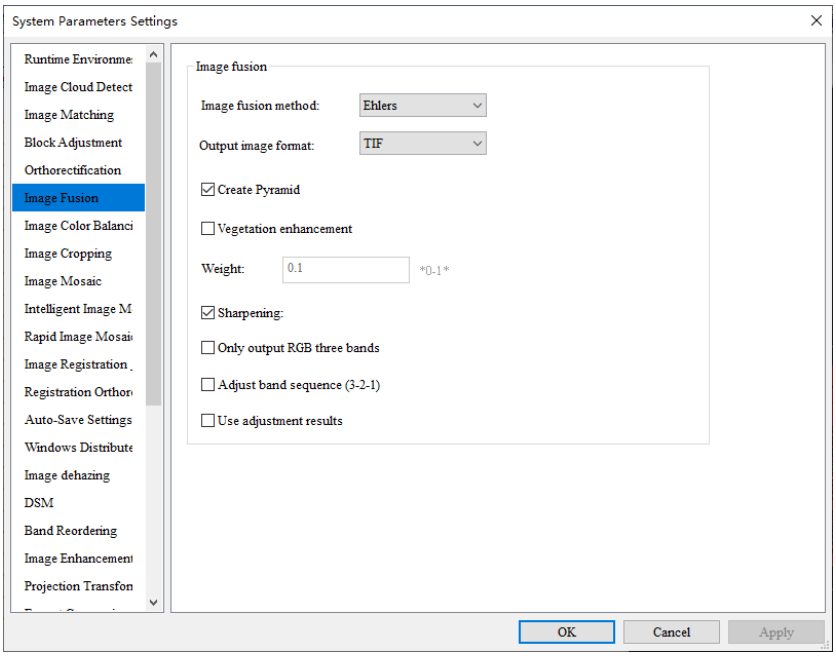


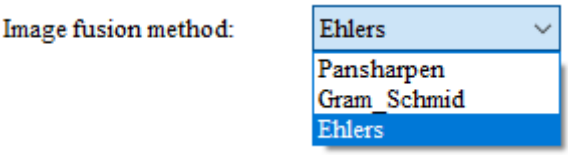
4.3 Provides fully automated rectification for distorted imagery

SVP provides a variety of rectification methods including rigid translation, similarity transformation, affine transformation, quadratic polynomial, cubic polynomial, thin plate spline, and 3D DLT. For imagery with significant distortion, such as JL1KF01C, the distortion correction algorithm workflow has been optimized to achieve orthorectification accuracy within 1 to 2 pixels.



5. Image Fusion

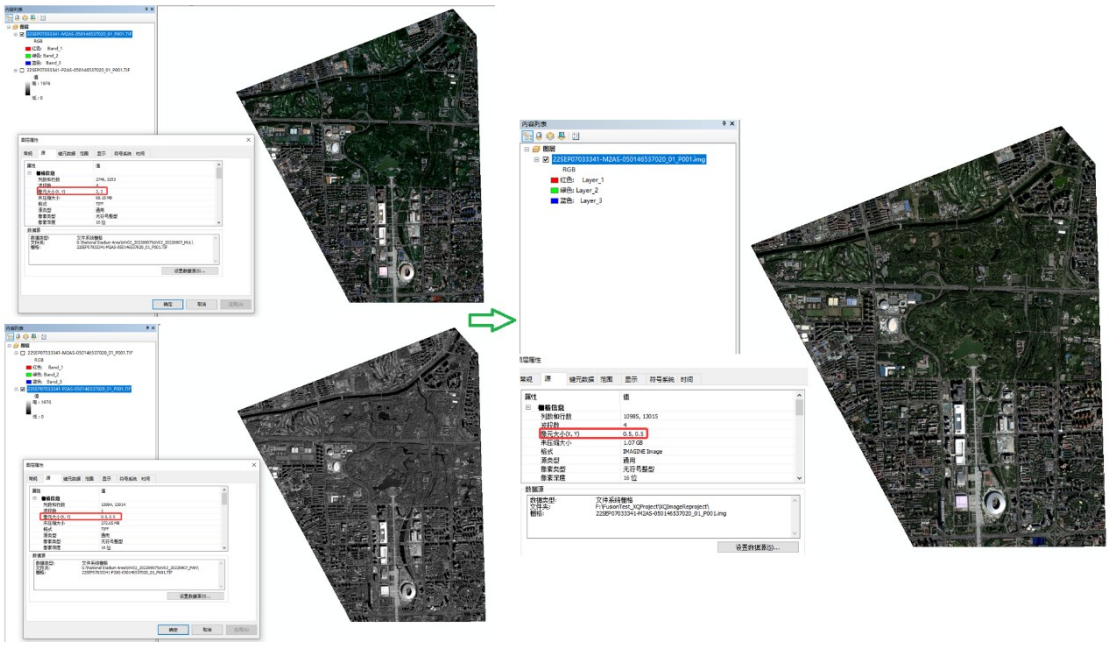




SVP provides different algorithms of image fusion，including Pansharpen, Gram Schmid and Ehlers. Users can select the appropriate fusion algorithm based on practical application requirements such as fusion processing speed, visual effect of the fusion result, and spectral analysis.

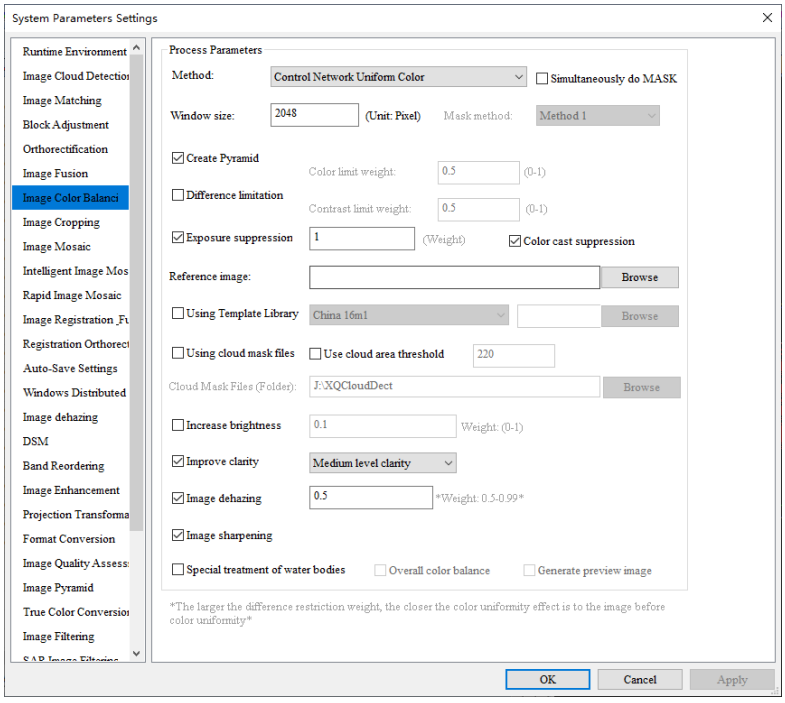
Before Fusion Processing

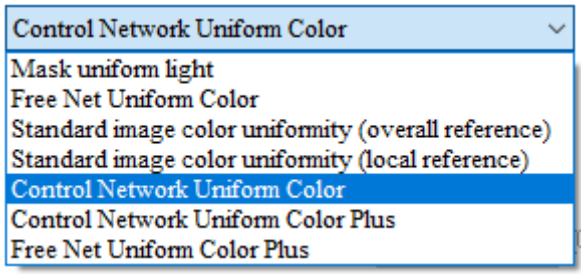
After Fusion Processing

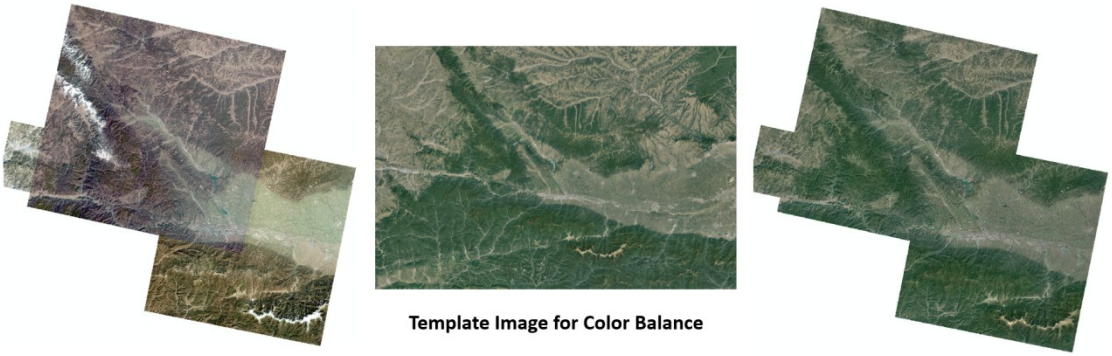


6. Image Dodging and Color Balancing

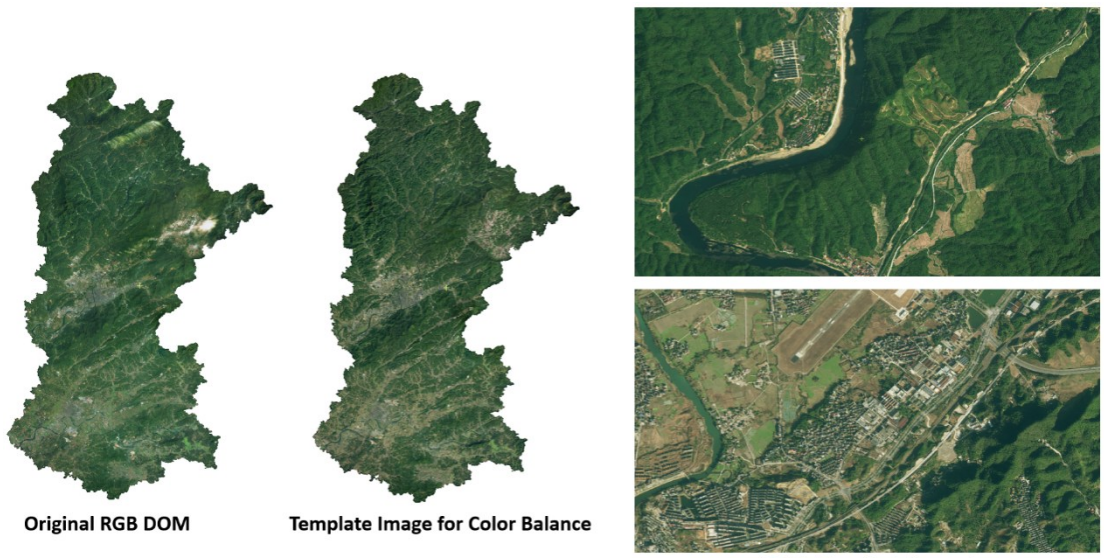
SVP provides different algorithms of image dodging and color balance， including Free Network Balancing, Standard Image Balancing (Global Reference), Standard Image Balancing (Local Reference), and Control Network Balancing. Also, SVP supports color balancing of 16-bit imagery, including both orthophotos and Level 1 raw imagery.





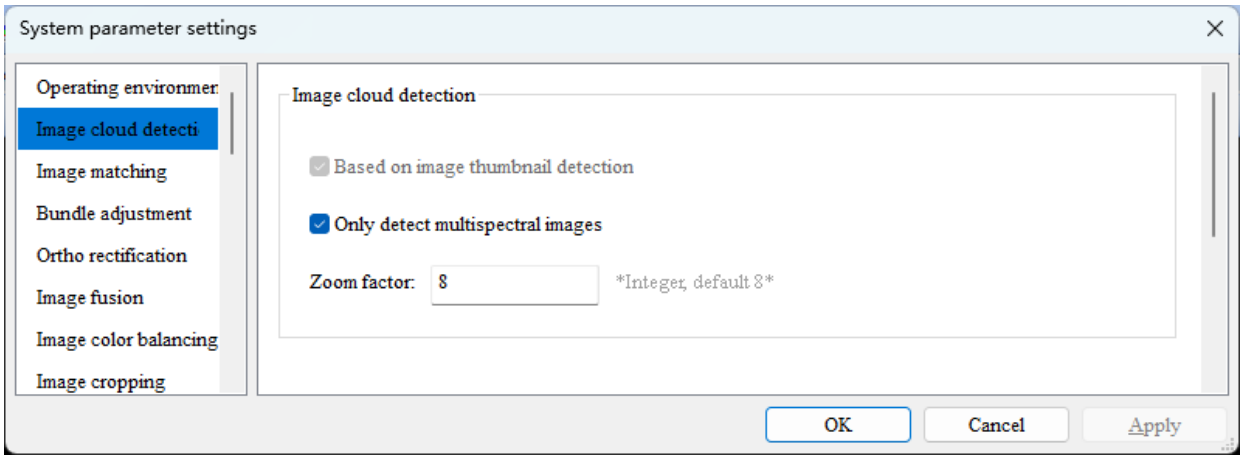


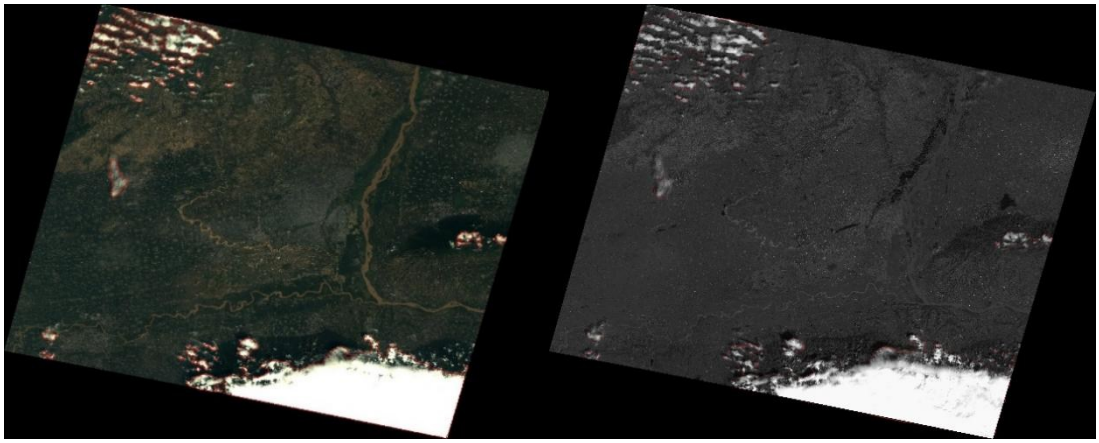
Color Balancing of Control Network and Free Network for Remote Sensing Images

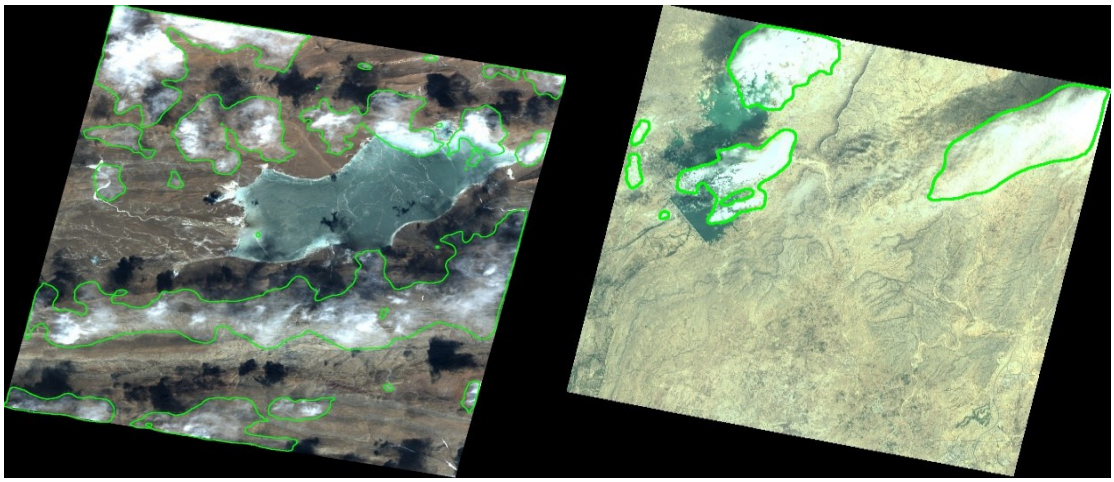


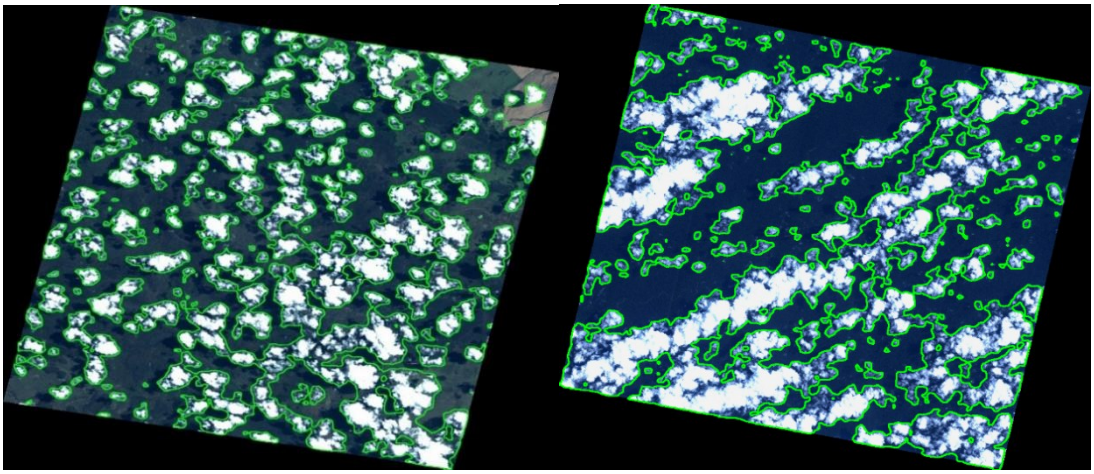
7.Automatic Cloud Detection

SVP integrates automatic cloud detection tool with AI algorithm that enables rapid and automated extraction of cloud-covered areas from massive remote sensing images. Both the vector data of cloud-covered areas and cloud mask images can be generated.



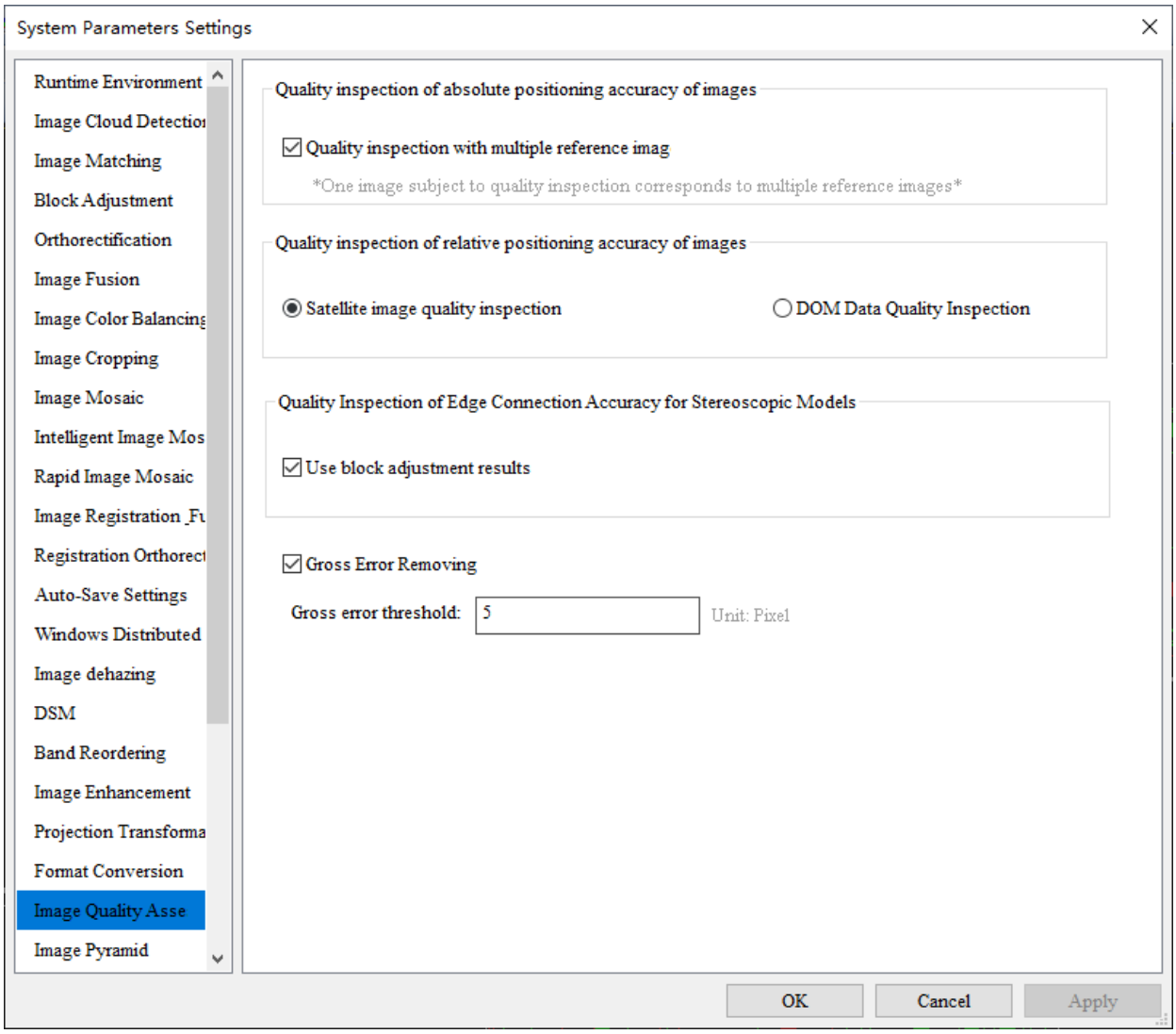


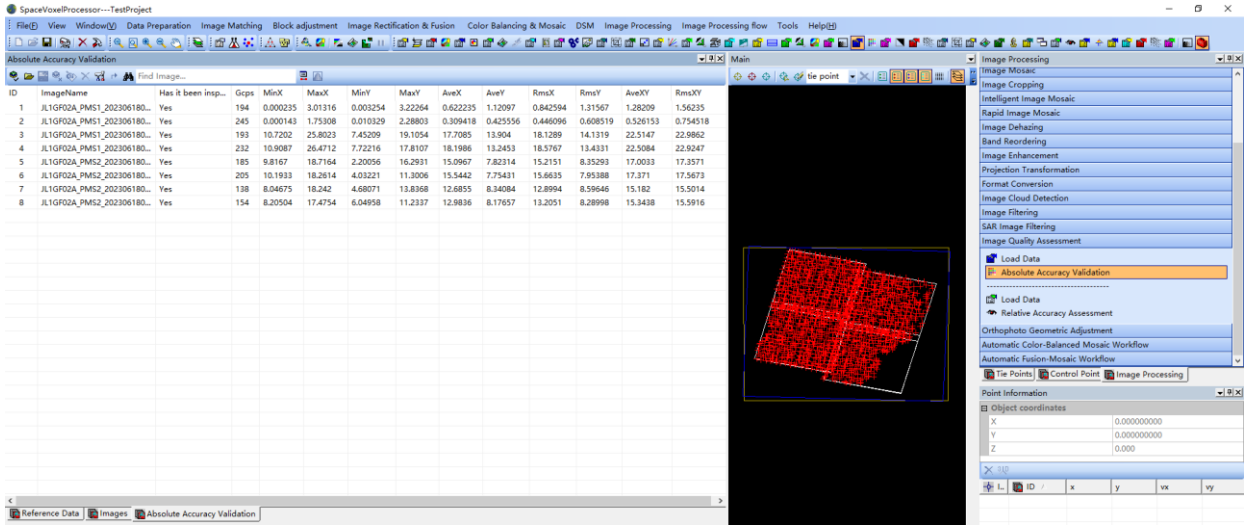




8.Complete Images Quality Assessment Tool

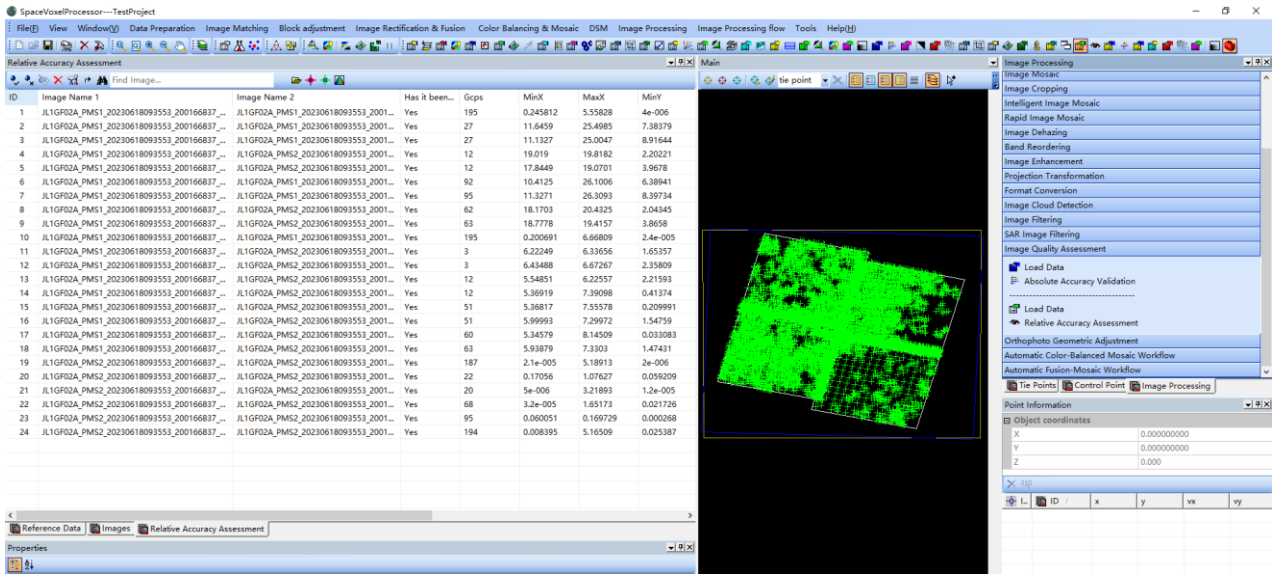
SVP integrates complete automatic image accuracy check tools, which include absolute accuracy validity, relative positioning accuracy check, accuracy check of stereo pair model edge connection. The image accuracy check tool can quickly perform accuracy checks on massive original images (single scene or stereo pair) and DOM products, also generate accuracy reports.





Accuracy Check.txt

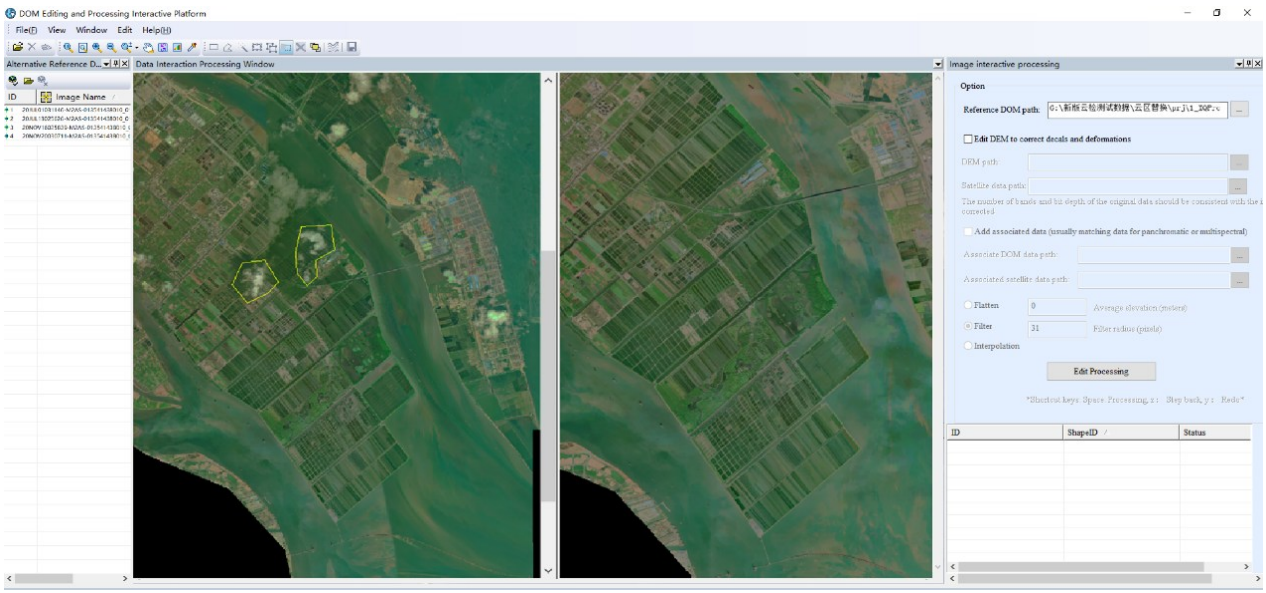
```
**********************************************************************
Gcps    MinX    MinY    MaxX    MaxY    AveX    AveY    RmsX    RmsY    AveXY   RmsXY   File
**********************************************************************
194 0.000235  0.003254  3.013165  3.222639  0.622235  1.120970  0.842594  1.315667  1.282088  1.562352  JL1GF02A_PMS1_20230618093553_200166837_102_0025_001
245 0.000143  0.010329  1.753078  2.288031  0.309418  0.425556  0.446096  0.608519  0.526153  0.754518  JL1GF02A_PMS1_20230618093553_200166837_102_0025_001
193 10.720202 7.452085  25.802314 19.105440 17.708527 13.904022 18.128877 14.131892 22.514745 22.986225 JL1GF02A_PMS1_20230618093553_200166837_102_0026_001
232 10.908732 7.722164  26.471180 17.810748 18.198587 13.245349 18.576728 13.433131 22.508395 22.924743 JL1GF02A_PMS1_20230618093553_200166837_102_0026_001
185 9.816705  2.200558  18.716389 16.293144 15.096733 7.823139  15.215064 8.352934  17.003319 17.357122 JL1GF02A_PMS2_20230618093553_200166837_102_0025_001
205 10.193331 4.032212  18.261391 11.300621 15.544175 7.754312  15.663537 7.953875  17.370974 17.567314 JL1GF02A_PMS2_20230618093553_200166837_102_0025_001
138 8.046754  4.680712  18.242021 13.836813 12.685510 8.340844  12.899381 8.596458  15.181958 15.501391 JL1GF02A_PMS2_20230618093553_200166837_102_0026_001
154 8.205040  6.049581  17.475412 11.233660 12.983622 8.176575  13.205094 8.289981  15.343755 15.591610 JL1GF02A_PMS2_20230618093553_200166837_102_0026_001
```



Gcps	MinX	MinY	MaxX	MaxY	AveX	AveY	RmsX	RmsY	AveXY	RmsXY	File
195	0.245812	0.000004	5.558279	6.871731	1.407311	0.958681	1.562472	1.349510	1.702819	2.064581	JL1GF02A_PMS1_20230618093553_200166837_102_0025_001
27	11.645947	7.383792	25.498461	16.455092	17.983837	12.486966	18.819133	13.007955	21.893897	22.877208	JL1GF02A_PMS1_20230618093553_200166837_102_0025_001
27	11.132708	8.916438	25.004711	16.275772	17.274141	13.021961	18.135247	13.476402	21.632555	22.594260	JL1GF02A_PMS1_20230618093553_200166837_102_0025_001
12	19.019040	2.202215	19.818151	4.790532	19.371143	3.748299	20.234115	4.007849	19.730457	20.627221	JL1GF02A_PMS1_20230618093553_200166837_102_0025_001
12	17.844885	3.967801	19.070054	5.737225	18.575617	5.242689	19.404917	5.503024	19.301278	20.170128	JL1GF02A_PMS1_20230618093553_200166837_102_0025_001
92	10.412489	6.389409	26.100552	18.682404	18.036951	12.939989	18.731833	13.368271	22.198534	23.012871	JL1GF02A_PMS1_20230618093553_200166837_102_0025_001
95	11.327125	8.397342	26.309282	15.789224	18.376494	12.603324	19.036964	12.862964	22.283162	22.975244	JL1GF02A_PMS1_20230618093553_200166837_102_0025_001
62	18.170306	2.043446	20.432481	6.321499	19.221716	4.541923	19.385233	4.682856	19.751036	19.942828	JL1GF02A_PMS1_20230618093553_200166837_102_0025_001
63	18.777841	3.865800	19.415659	7.062802	19.161357	5.402771	19.316279	5.503681	19.908479	20.085048	JL1GF02A_PMS1_20230618093553_200166837_102_0025_001
195	0.200691	0.000024	6.668087	7.000664	1.456624	1.831767	1.760382	2.144300	2.340326	2.774341	JL1GF02A_PMS1_20230618093553_200166837_102_0026_001
3	6.222485	1.653571	6.336557	2.593514	6.288801	2.111658	7.702405	2.628678	6.633861	8.138611	JL1GF02A_PMS1_20230618093553_200166837_102_0026_001_L
3	6.434876	2.358089	6.672668	2.553340	6.535030	2.470292	8.004694	3.027158	6.986341	8.557968	JL1GF02A_PMS1_20230618093553_200166837_102_0026_001_L
12	5.548514	2.215931	6.225572	4.794135	5.874746	3.633673	6.140515	3.839075	6.907693	7.241852	JL1GF02A_PMS1_20230618093553_200166837_102_0026_001
12	5.369191	0.413740	7.390981	4.049941	6.805925	1.923109	7.128522	2.240105	7.072409	7.472208	JL1GF02A_PMS1_20230618093553_200166837_102_0026_001
51	5.368174	0.209991	7.555778	4.670363	6.671159	2.760544	6.754672	2.966224	7.219762	7.377268	JL1GF02A_PMS1_20230618093553_200166837_102_0026_001
51	5.999925	1.547585	7.299718	3.129085	6.743613	2.296171	6.826779	2.382386	7.123813	7.230538	JL1GF02A_PMS1_20230618093553_200166837_102_0026_001
60	5.345792	0.033083	8.145092	4.708800	6.696020	2.612959	6.783304	2.900759	7.187784	7.377507	JL1GF02A_PMS1_20230618093553_200166837_102_0026_001
63	5.938793	1.474307	7.330303	3.075685	6.702834	2.293317	6.770958	2.371221	7.084299	7.174159	JL1GF02A_PMS1_20230618093553_200166837_102_0026_001
187	0.000021	0.000002	5.189134	5.918303	0.922871	1.174412	1.169311	1.661642	1.493631	2.031832	JL1GF02A_PMS2_20230618093553_200166837_102_0025_001
22	0.170560	0.059209	1.076272	1.632594	0.497703	0.658759	0.538976	0.745500	0.825634	0.919927	JL1GF02A_PMS2_20230618093553_200166837_102_0025_001
20	0.000005	0.000012	3.218933	3.179306	0.867705	0.960020	1.238289	1.404550	1.294044	1.872464	JL1GF02A_PMS2_20230618093553_200166837_102_0025_001
68	0.000032	0.021726	1.651732	6.368656	0.397956	1.193728	0.525876	1.644616	1.258315	1.726646	JL1GF02A_PMS2_20230618093553_200166837_102_0025_001
95	0.060051	0.000268	0.169729	0.058746	0.100706	0.023722	0.103433	0.028884	0.103462	0.107390	JL1GF02A_PMS2_20230618093553_200166837_102_0025_001
194	0.008395	0.025387	5.165092	7.367012	1.129800	1.223779	1.470696	1.662931	1.665558	2.219974	JL1GF02A_PMS2_20230618093553_200166837_102_0026_001

9.One-click, multi-task parallel cloud replacement processing of remote sensing images

SVP provides a fast and efficient cloud replacement tool, which performs one-click replacement of cloud-covered areas in remote sensing images based on the cloud coverage obtained through cloud detection.



10.Interactive editing for image distortion and one-click restoration

SVP provides user-friendly orthophoto editing tools that allow for efficient editing of distorted and blurred areas in DOM.