



# 6th Asia-Oceania Group on Earth Observations (**AOGEO**) Workshop

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## *Production and Key Technology for Gaofen 16 meter Analysis Ready Data*

*Ping Tang, Lianzhi Huo, Changmiao Hu, Xiaojun Shan, Bo Zhong,  
Aixia Yang, Shanlong Wu, Zhao Wang, Hao Chang, Zheng Zhang*

*Areospace Information Research Institute, CAS*

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## 1. Overview of Gaofen 16m Analysis Ready Data (ARD)



Gaofen 1 launched in  
April, 2013



Gaofen 6 launched in  
June, 2018

- Gaofen (GF) 16 meter data comes from China's high-resolution earth observation system, GF1 satellite and GF6 satellite.
- GF6 can be networked with GF1 satellite. The satellite revisit period is shortened to 2 days.
- GF 1/6 meter data can be used for crop and farmland environment monitoring.

Sensor(s)	Platform	Spatial Resolution	Swath	Spectra	Lauching Year
4 WFVs	GF1	16m	800km(4cams)	VIS, NIR	2013
1 WFV	GF6	16m	800km	DB, VIS, NIR, Red edge	2018

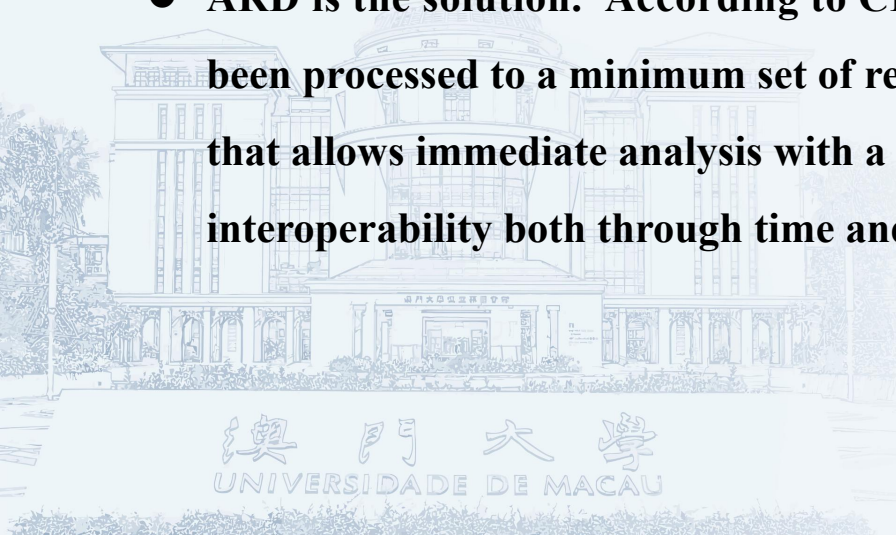


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- In the 2019 GEO WEEK, China has announced that open share policy for the 16 meter GF satellite data. But the shared GF data is in the L1A preprocessing level. The end-users will inevitably face different preprocessing steps for the GF data before focusing on their domain tasks.
- ARD is the solution. According to CEOS: ARD are satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and with other datasets.



The website for the Gaofen data sharing [www.cnsageo.com](http://www.cnsageo.com)



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## GF1/GF6 ARD

### Radiometric Processing

**Sensor calibration**  
**Atmosphere correction**

### Geometric Processing

**RPC correction +**  
**Correction based on control points**

### Quality Assessment

**Cloud / Shadow area labeling**

**Data Tiling and Projection**

## GF1/GF6 ARD+

**Synthesis and Area Repairing**

**Cloud / Shadow area repaired**

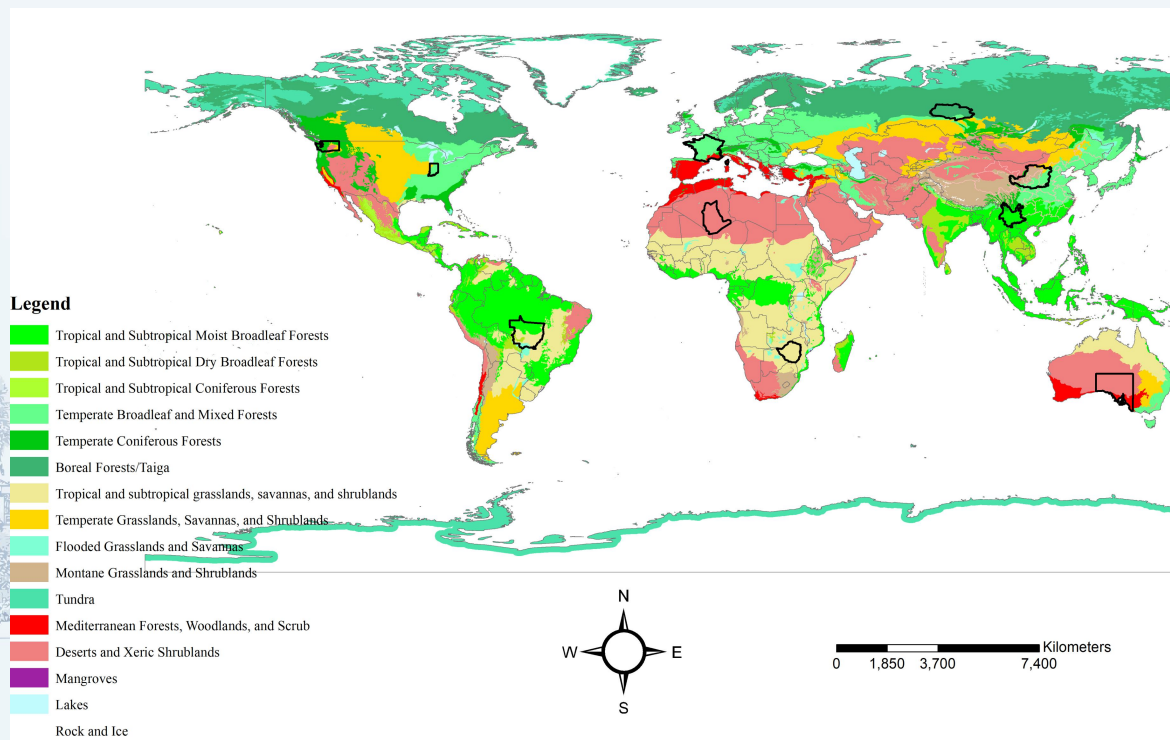
## GF1/GF6 ARD++

**Building Dense Series**  
**with Multi-sensor ARD+**

## Processing Flowchart of ARD

## 2. Test Data Introduction

Based on Olson's World Eco-region map, we selected 10 study areas data around the world. In total, 39,594 images were downloaded, about 120TB data.



No.	Region	GF1	GF6	Continent
1	Mato Grosso, Brazil	471	1521	South America
2	France	2542	936	Europe
3	Washington State, USA	2297	1141	North America
4	Indiana State, USA			
5	South Australia State, Australia	347	808	Australia
6	Zimbabwe	160	245	Africa
7	Algeria	944	1068	Africa
8	Yunnan Province, China	5769	1195	Asia
9	Loess Plateau, China	17228	2320	Asia
10	Tomsk, Russia	241	361	Europe
Total		29999	9595	

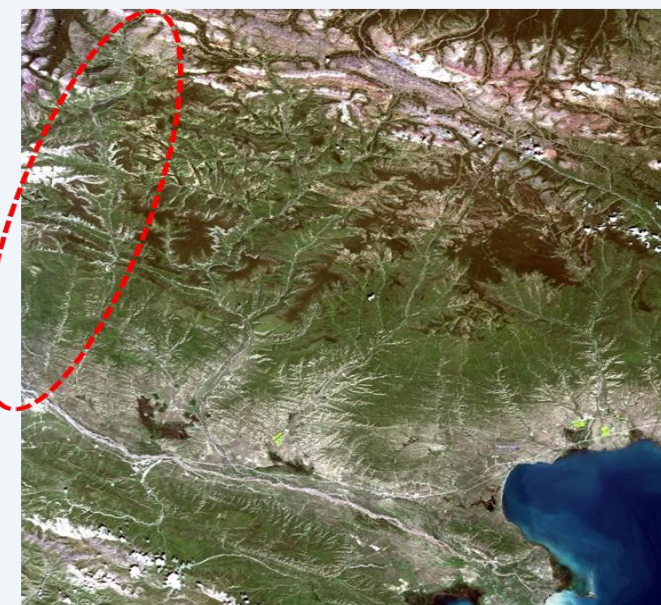
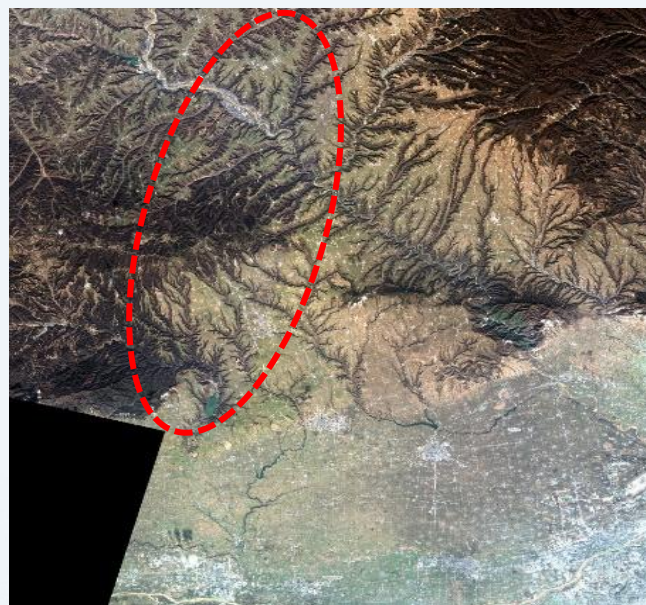
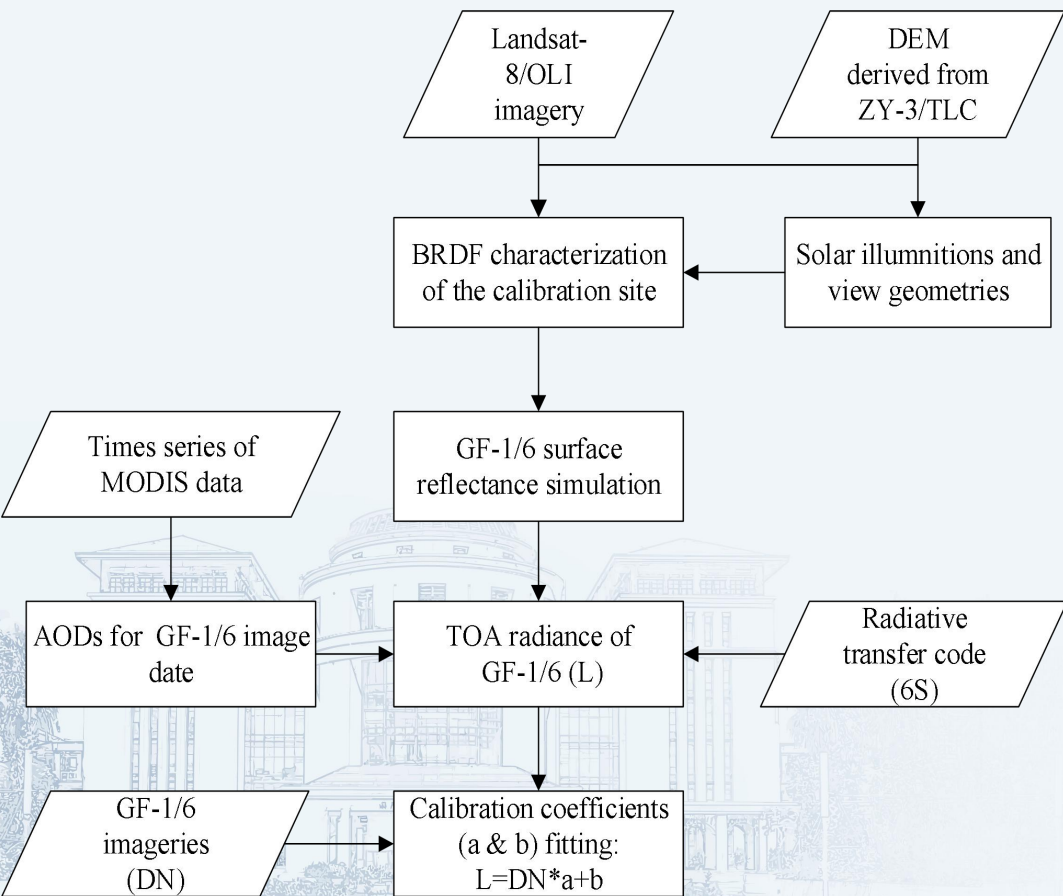
## 3. Radiometric Processing

- ❑ Radiometric normalization after sensor calibration. There are radiation differences existed between GF1 and GF6.



- ❑ Cross-Calibration method based on Landsat and DEM was proposed
- ❑ Cross-Calibration coefficients were produced for GF1 from 2013 to now, GF6 from 2018 to now

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After radiometric processing

Radiation average error < 3.73%

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Our algorithm



- ❑ **Atmospheric correction.** Due to lacking the 2.1  $\mu\text{m}$  band for GF1/6, it has remained a challenge to retrieve the aerosol optical depth (AOD) at 550 nm from moderate to high spatial-resolution optical imagery in arid areas with bright surfaces, such as deserts and bare ground.
- ❑ The new high-brightness surface reflectance algorithm based on BRDF library has been integrated into algorithm system.
- ❑ Construct a global stable surface albedo library so that the algorithm can perform global data processing.

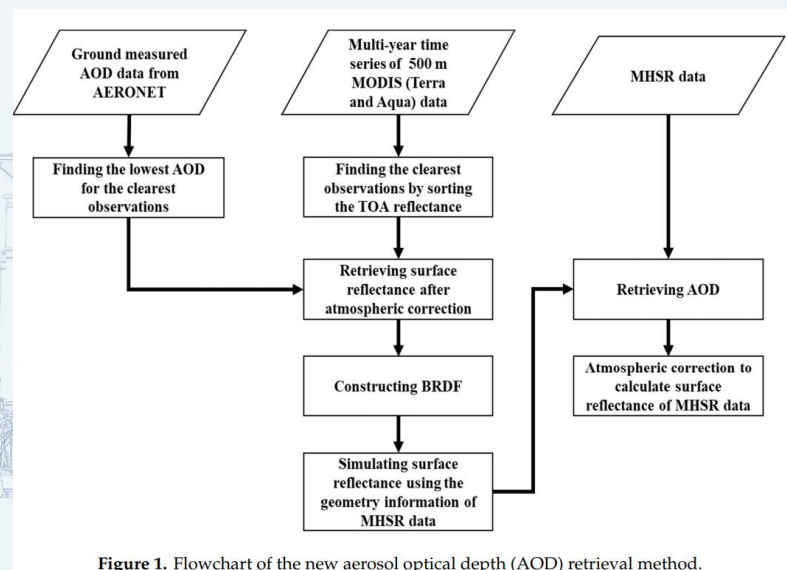
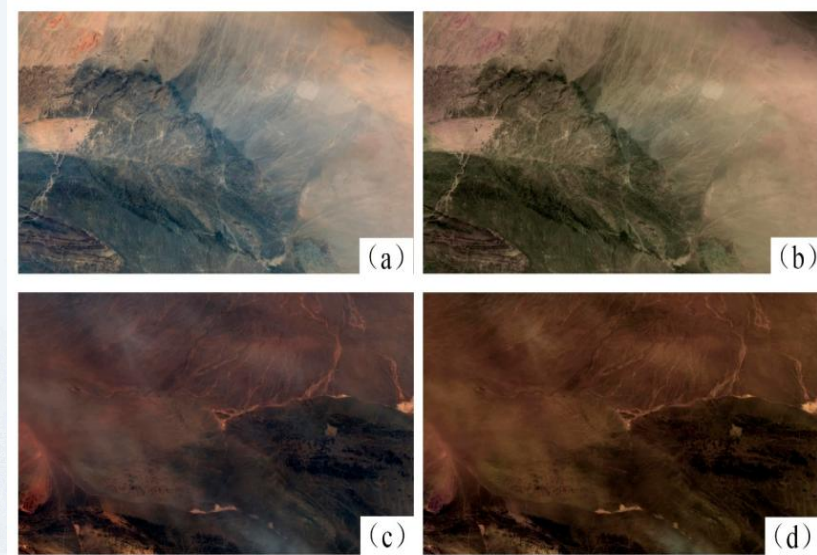


Figure 1. Flowchart of the new aerosol optical depth (AOD) retrieval method.



The effect of the atmospheric correction

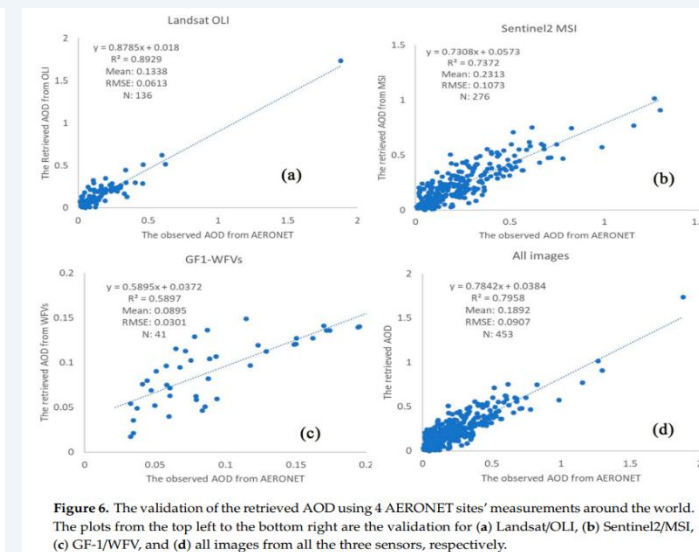


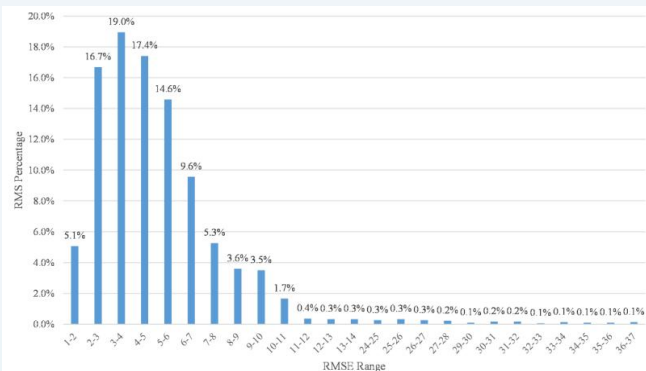
Figure 6. The validation of the retrieved AOD using 4 AERONET sites' measurements around the world. The plots from the top left to the bottom right are the validation for (a) Landsat/OLI, (b) Sentinel2/MSI, (c) GF-1/WFV, and (d) all images from all the three sensors, respectively.

Validation of the retrieved AOD using 4 AERONET sites around the world

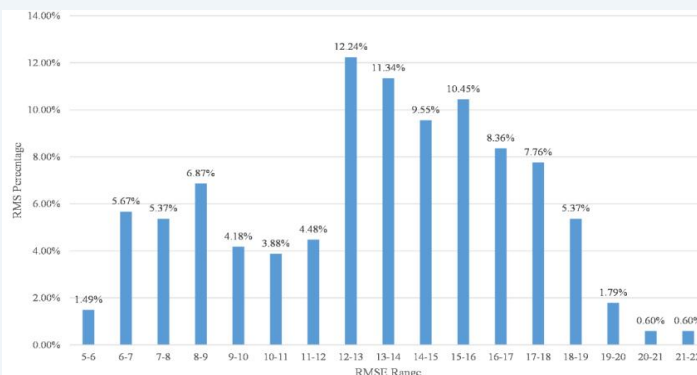
## 4. Geometric Processing

### □ Geometric Accuracy by only performing RPC correction

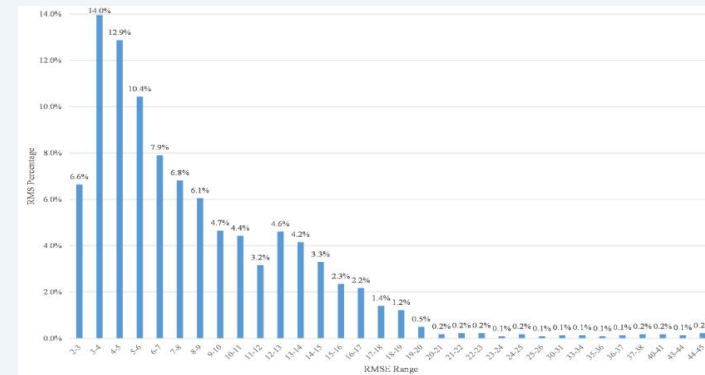
GF 1



**China: 96.3% (2990 images) RMSE: 1-11 pixels.**

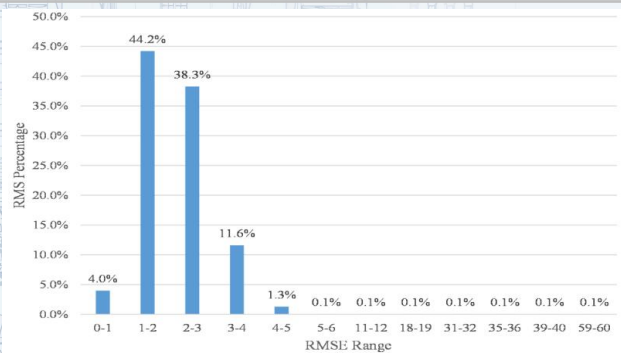


**Brazil: (355 images) RMSE: 5-22 pixels.**

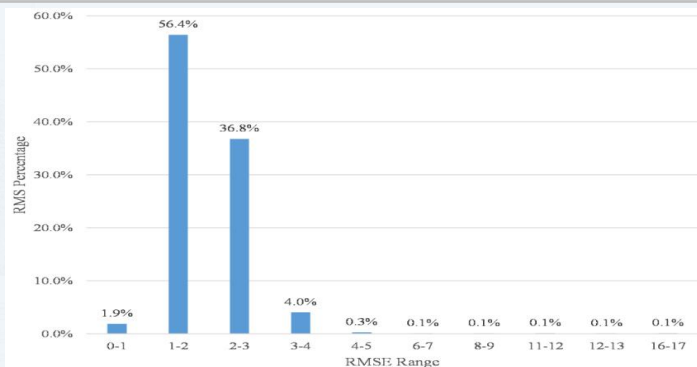


**France: 93.5% (2214 images) RMSE: 2-19 pixels.**

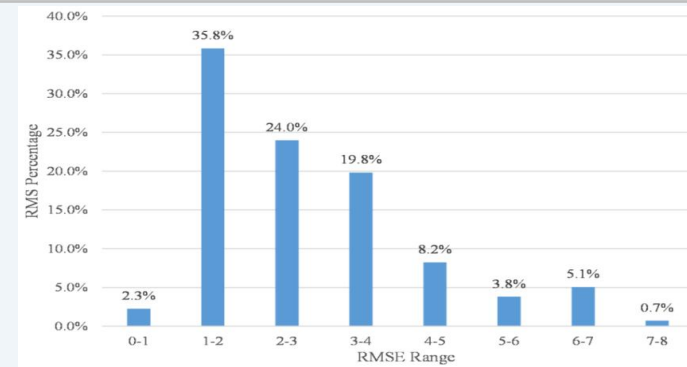
GF 6



**China: 99.4% (1077 images) RMSE: 0-5 pixels.**

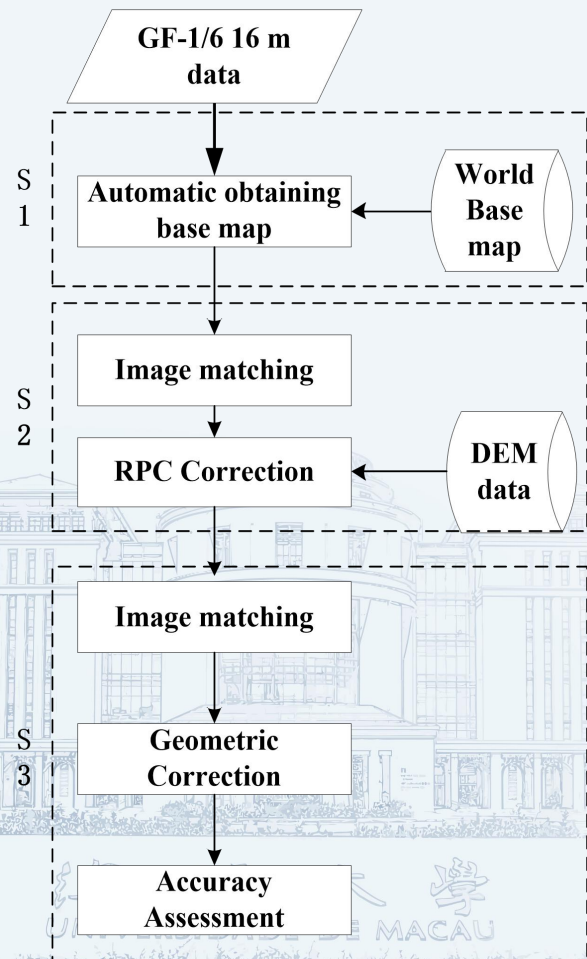


**Brazil: 99.1% (2840 images) RMSE: 0-17 pixels.**



**France: 99% (1105 images) RMSE: 0-7 pixels.**

## ❑ RPC Correction + Image Matching + Geometric Correction



### GF 1

RMSE	Percentage		
Range (Pixel)	China	France	Brazil
<b>0-0.8</b>	98.0%	91.1%	94.9%
0.8-1.0	1.3%	7.0%	3.7%
> 1.0	0.7%	1.9%	1.4%

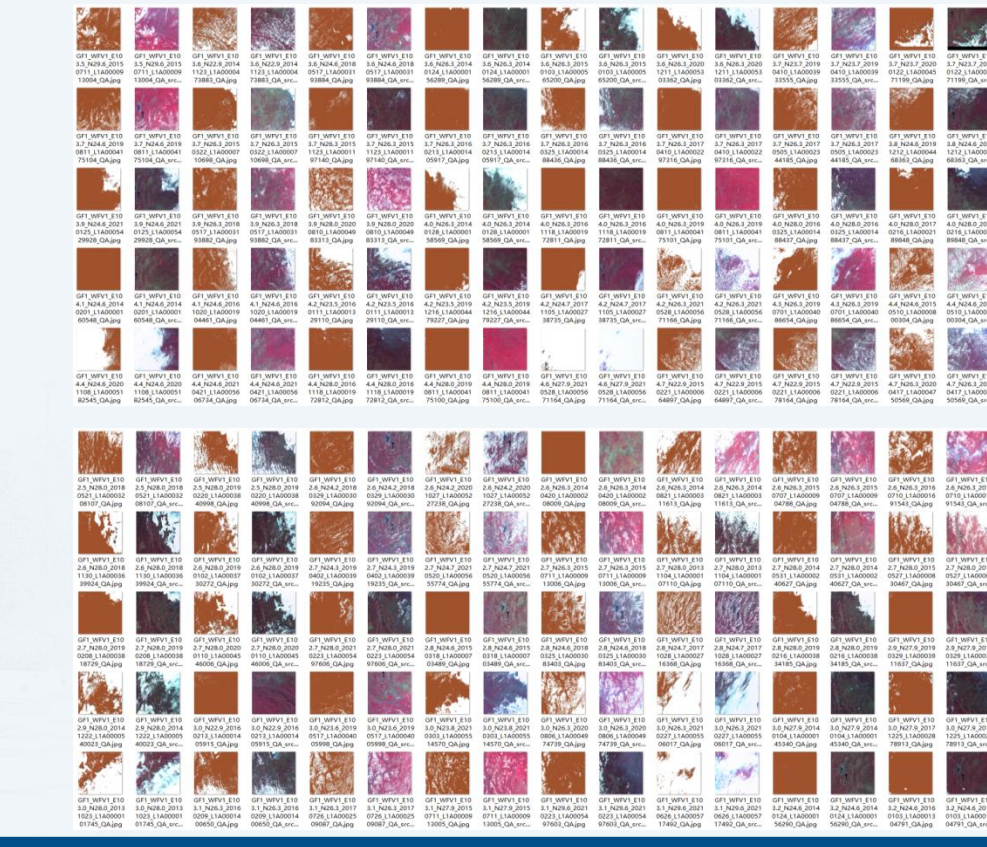
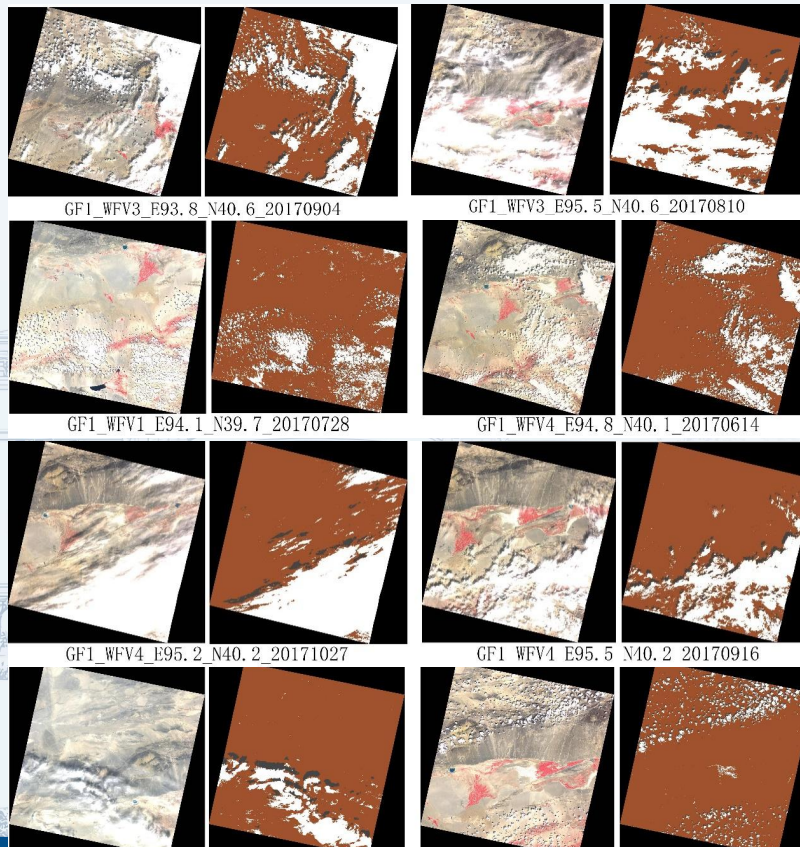
### GF 6

RMSE	Percentage		
Range (Pixel)	China	France	Brazil
<b>0-0.8</b>	93.0%	91.0%	92.1%
0.8-1.0	5.0%	6.1%	4.9%
> 1.0	0.7%	2.9%	3.0%

**Only accuracy is better than 0.8 pixel are used for ARD production**

## 5. Quality Assessment - Cloud/Shadow Mask

Following the strategy of the Fmask algorithm, we first developed logical decision tree based rules to mask cloud and cloud shadow, then boundary refinement was performed based on geometric relationship between cloud and shadows.



Only images with cloud and shadow coverage <80% are used for ARD production

Further, we developed GF1/GF6 pixel-by-pixel quality tagging algorithm based on deep learning method (i.e., Swin Transformer model). Validation of more data is in progress.

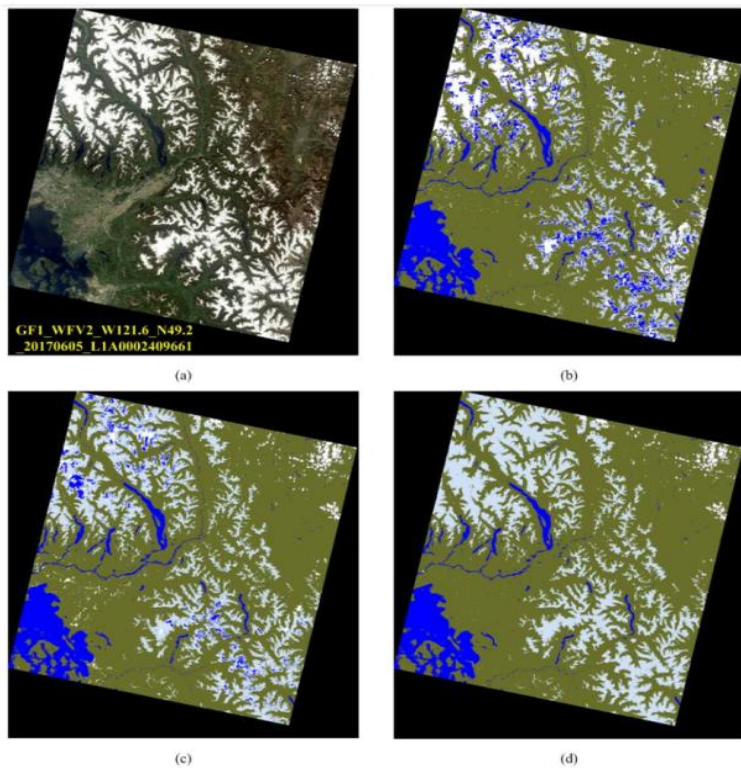
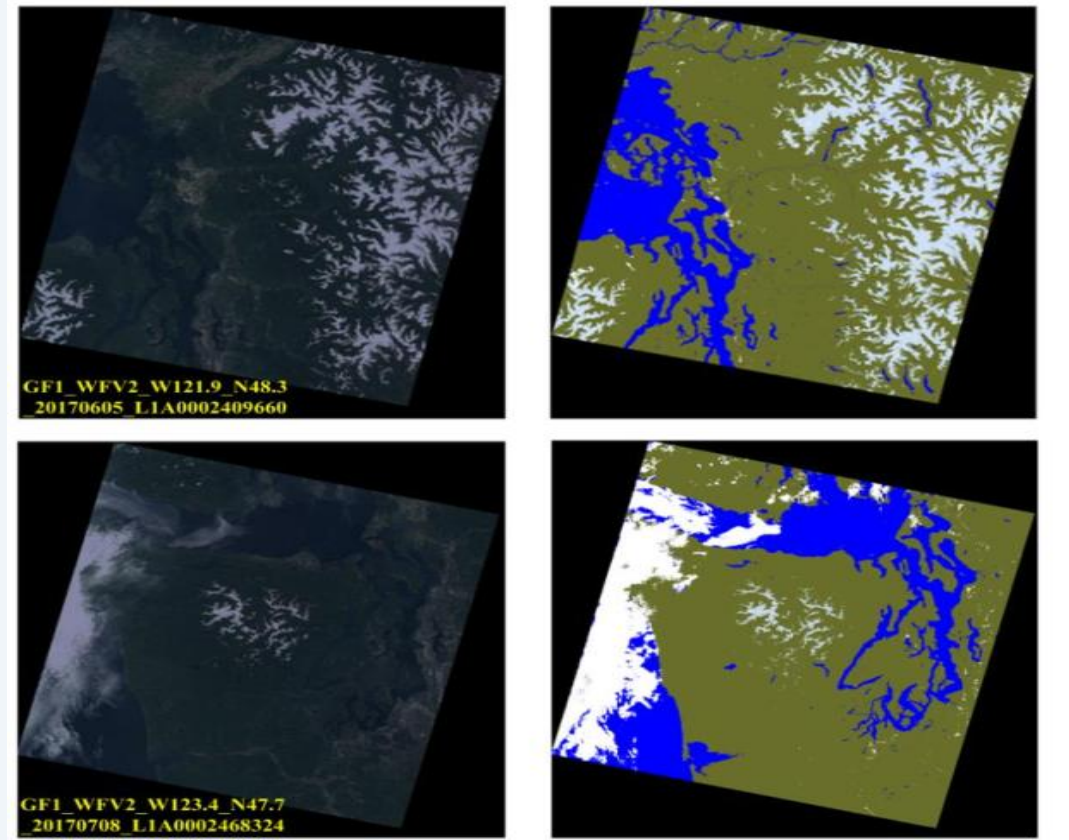


Figure 16. Example GF-1 WFV image and quality tagging masks produced by different training sample numbers of Swin-L models. (a) RGB source image; (b) 2k samples based on Swin-L mask; (c) 5k samples based on Swin-L mask; (d) 10k samples based on Swin-L mask.



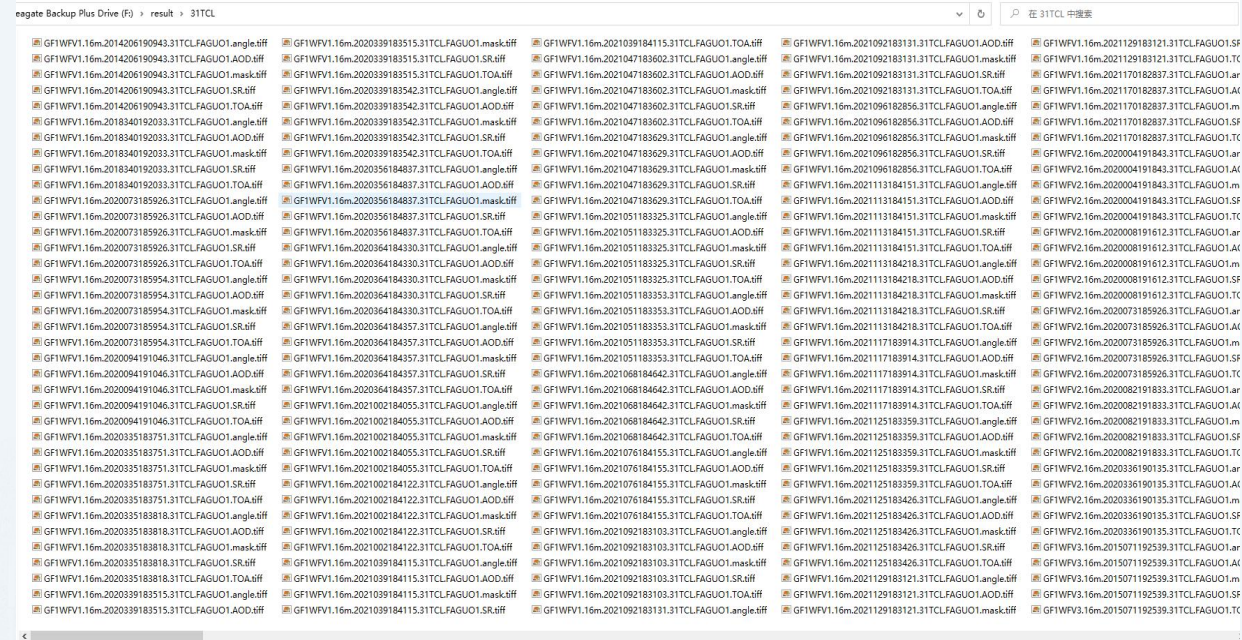
## 6. Data Tiling and Projection

For consistency with other similar sensors, GF ARD is stored with Military Grid Reference System (MGRS) tile system. For 16 meter spatial resolution, each tile is with 6863 × 6863 pixels.

表 5 ARD 产品数据说明

序号	产品名称	波段数量	数据类型	比例因子	填充值	说明
0	角度数据 Angle	4	unsigned 16-bit	100	0	波段 1: SolarAzimuthAngle 波段 2: SolarZenithAngle 波段 3: ViewAzimuthAngle 波段 4: ViewZenithAngle
1	表观反射率数据 TOA	4 (GF 1) 8 (GF 6)	unsigned 16-bit	10000	0	表观反射率
2	气溶胶光学厚度 AOD	1	unsigned 16-bit	10000	0	气溶胶光学厚度
3	地表反射率 SR	4 (GF 1) 8 (GF 6)	unsigned 16-bit	10000	0	地表反射率
4	云掩膜 Mask	1	unsigned 8-bit	Null	0	ClearPixel=1 WaterPixel=2 CloudShadowPixel=3 SnowPixel=4 CloudPixel=5 FillPixel=0

- GF1WV1.16m.2014206190943.31TCL.000123.angle.tiff
- GF1WV1.16m.2014206190943.31TCL.000123.AOD.tiff
- GF1WV1.16m.2014206190943.31TCL.000123.mask.tiff
- GF1WV1.16m.2014206190943.31TCL.000123.SR.tiff
- GF1WV1.16m.2014206190943.31TCL.000123.TOA.tiff



Tiles stored in GeoTiff files

The naming convention is: GF1WV1.16m.2014206190943.31TCL.000123.SR.tiff

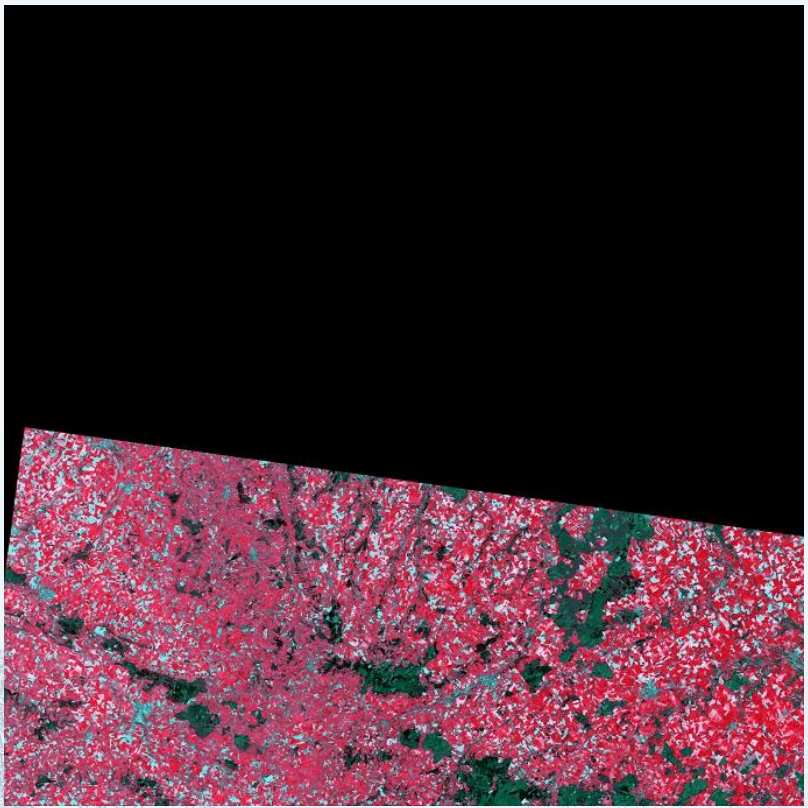
2014206190943 indicates the time of the data imaging center is 206 days, 19 hours, 09 minutes and 43 seconds in 2014;

31TCL indicates the MGRS number

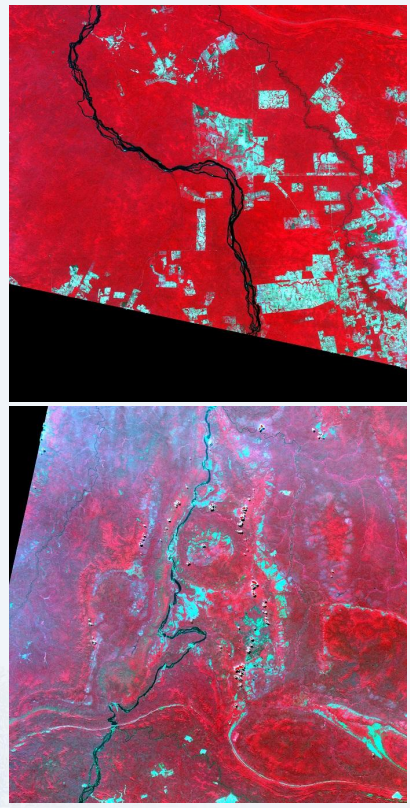
000123 indicates the processing version name

SR indicates that the product type is surface reflectance

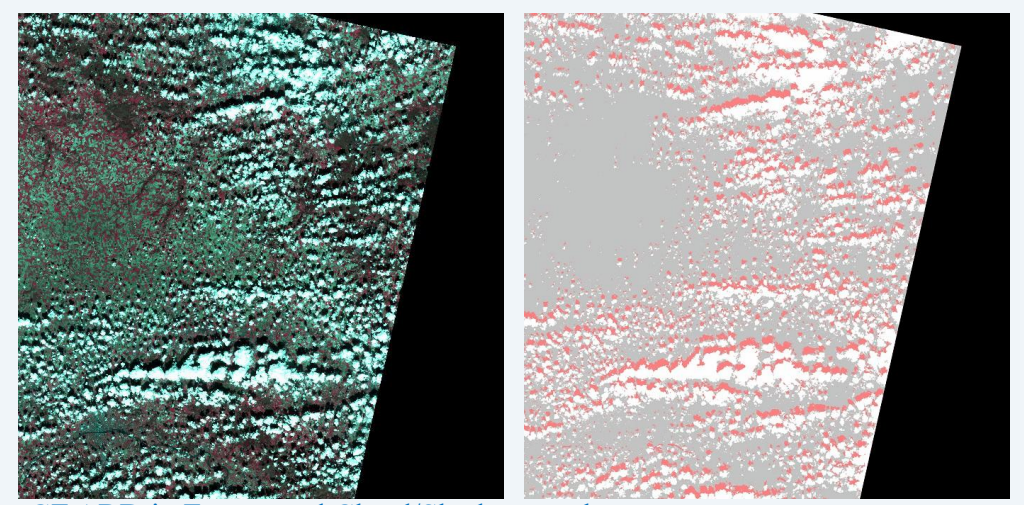
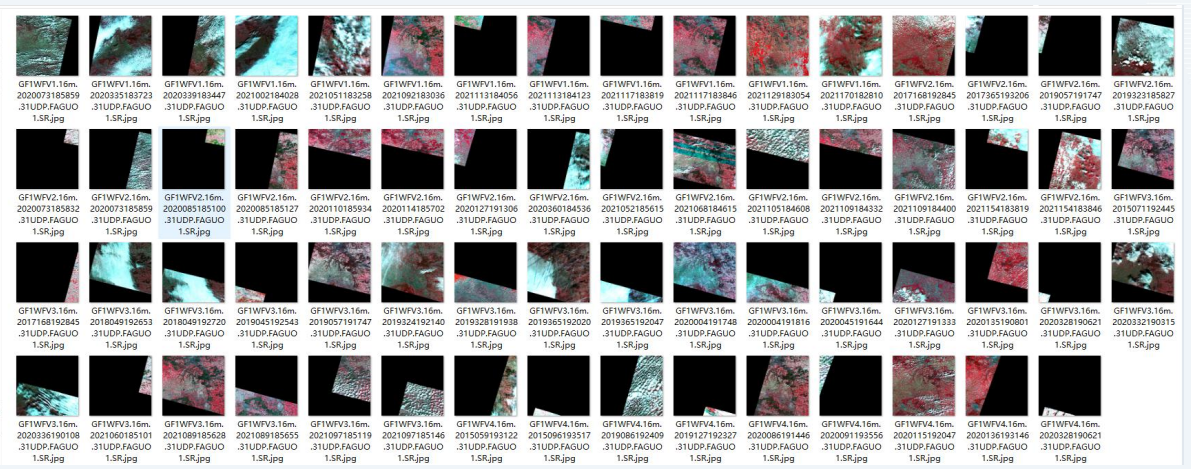
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GF ARD in Rouen, France  
(tile: 30UYV; 2015-2021)



Gaofen ARD in Amazon forest  
(21LUK, 21LUL; Aug. 2017)

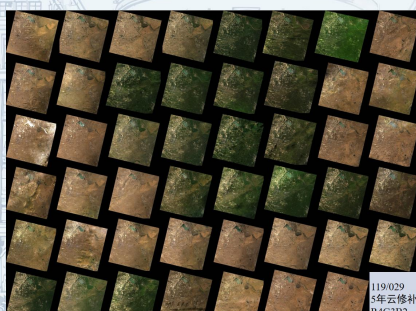
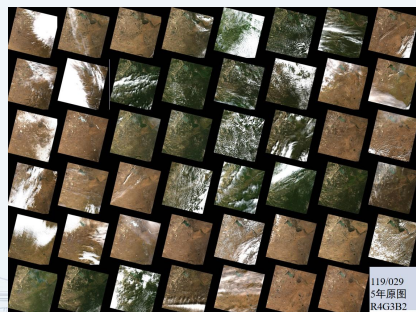
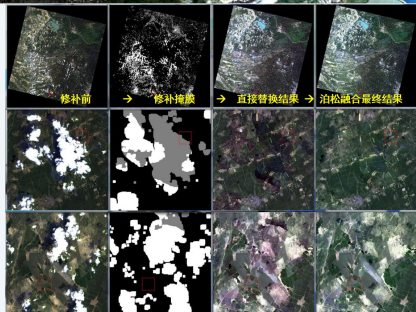


GF ARD in France and Cloud/Shadow mask  
(Tile: 31UDP; 2015-2021; White: Cloud; Pink: Shadow; Grey: Normal)

68 tiles in the French study area, 72 tiles in the Brazilian study area

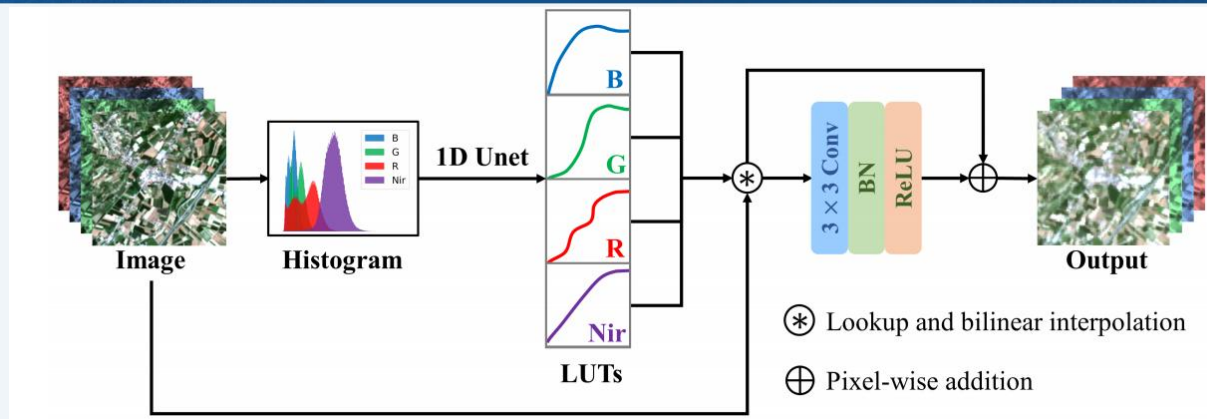


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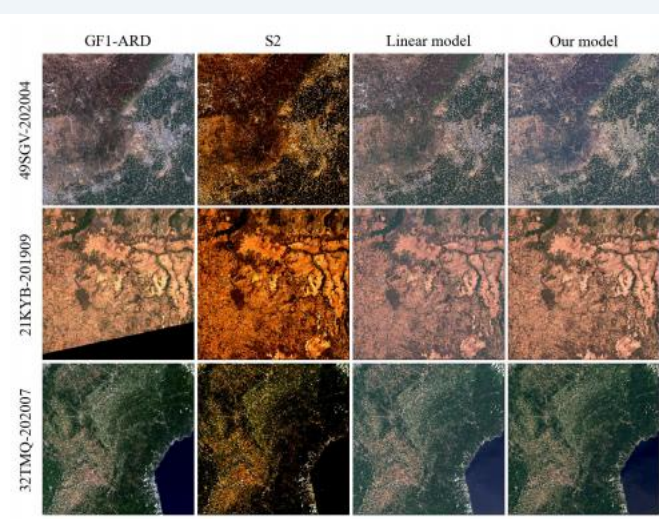
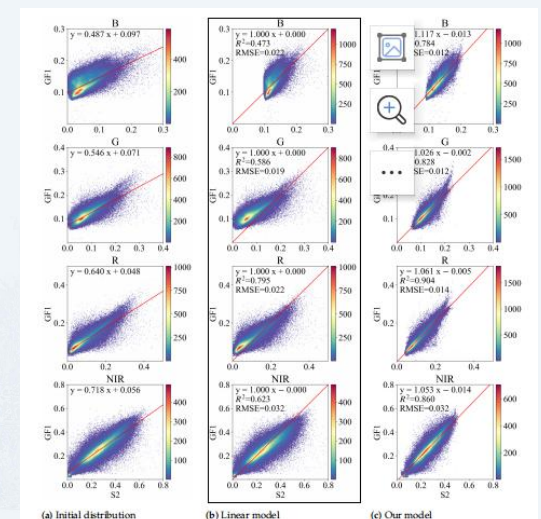


119 029  
5年原图  
R4G3B2

119 029  
5年云修补  
R4G3B2



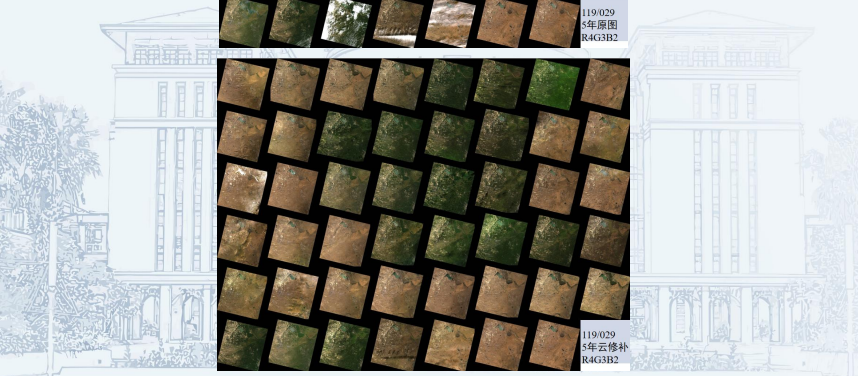
## Algorithms for ARD+ ARD++



## Algorithms to repair cloud/cloud shadow areas

## Bandpass Alignment from Sentinel-2 to GF ARD

Liu, Z.-Q. etc., Bandpass Alignment from Sentinel-2 to Gaofen-1 ARD Products with UNet-Induced Tile-Adaptive Lookup Tables. Remote Sens. 2023, 15, 2563.

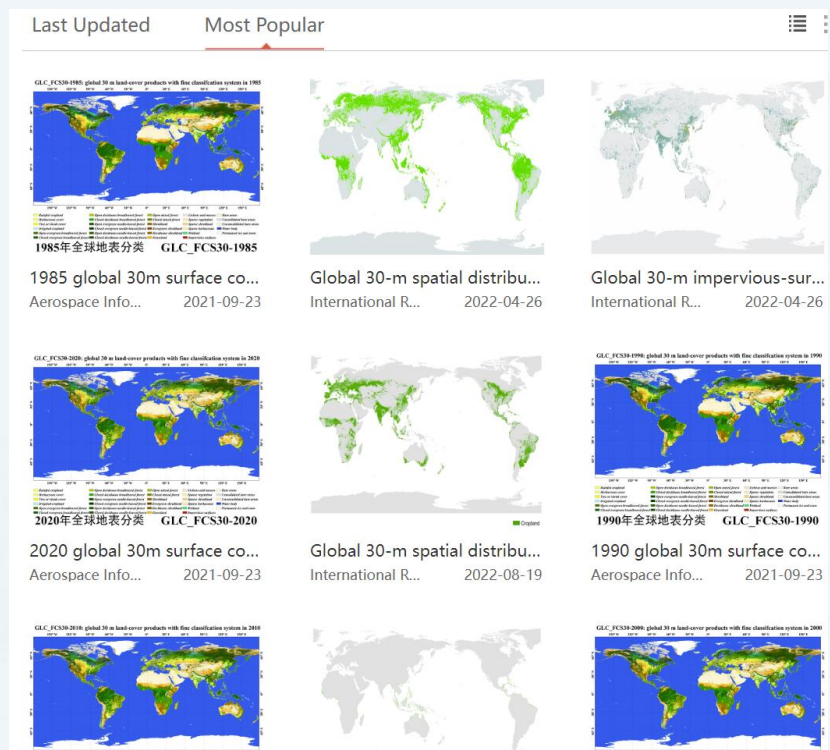
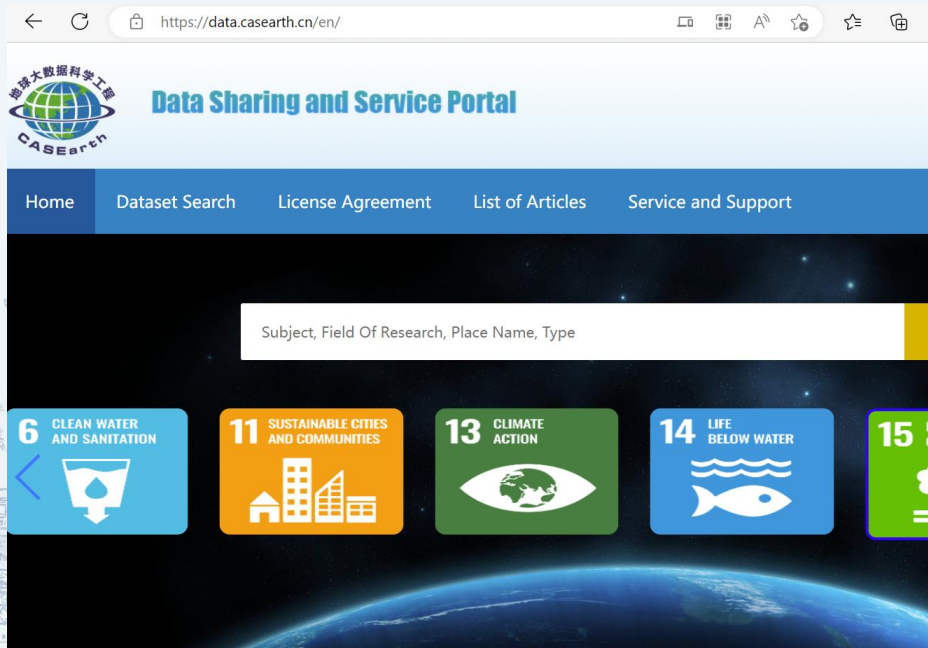


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## 7. Data Sharing Portal

GF 16m ARD will be released in <https://data.casearth.cn/en/> in Sep.



Data volume: 16PB  
No. of files: 125 million  
Views: 11458998  
Downloads: 1712769

## 8. Conclusion

- ❑ ARD is a great way to organize and deliver satellite data.
- ❑ We have made great progress in GF data processing through the production of GF ARD, there are still many challenges.
- ❑ The incomplete time series of GF data outside of China will affect its potential for global application.
- ❑ Providing continuous and high-quality GF 16m ARD for sharing is our goal.





Earth Observations  
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# *THANKS*

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<https://aogeo-workshop-2022.casconf.cn/>

Email: [aogeo\\_china@aircas.ac.cn](mailto:aogeo_china@aircas.ac.cn)