

## A System for Automatic Processing of MODIS L1B Data

Lingkui Meng<sup>+</sup>, Liang Tao, Jiyuan Li and Chunxiang Wang

School of Remote Sensing and Information Engineering, Wuhan University,  
129 Luoyu Road, Wuhan 430079, P.R. China

**Abstract.** MODIS is an important sensor of EOS program. In this paper we introduce the main characteristics of MODIS L1B data and its application status. Then we design the MODIS L1B Data Automatic Processing System, explaining its concept, main function and realization of the system. Meanwhile, the products of the system include: L1B radiance products, L1B reflectance products, day NDVI mosaic image, colored composite mosaic image, brightness temperature mosaic image, ten-day period NDVI mosaic image, etc. Finally, we sum up the system, give spatial accuracy assessment, optimization strategy and point out future work.

**Keywords:** MODIS L1B, automatic process, ENVI, bow-tie, mosaic, NDVI, brightness temperature.

### 1. Introduction

MODIS (MODerate resolution Imaging Spectroradiometer) is an important sensor of EOS program. It is one of the main detection instrument onboard the TERRA and AQUA satellites. Compared with the previous satellite detectors, it has some specific characteristics, plus its globally free data-receive policy. All those make MODIS attract more scientific research attention.

According to traditional sensor, MODIS has advantages in the balance among time resolution, spatial resolution and spectrum resolution, mainly in three aspects:

The spectrum range is from 0.4 $\mu$ m to 14.3 $\mu$ m, 36 bands in all, has relative high radiate resolution.

- (1) The spatial resolution in band1 and band2 is 250m, from band3 to band7 spatial resolution is 500m, and from band8 to band36 spatial resolution is 1000m. Meanwhile the width for scan reaches 2330km.
- (2) In the time resolution aspect, people can get the global observation data less than two days.

MODIS Level 1B datasets have three earth view (EV) product files and one on-board calibrator (OBC) product file. Table 1 shows MODIS L1B Products.

The format of the MODIS L1B Products is the widely used Hierarchical Data Format (HDF).HDF is the standard data storage format selected by the Earth Observing System Data and Information System (EOSDIS) Core System. Broadly speaking, HDF is designed to allow sharing of self-describing files across heterogeneous platforms.

Table 1: Summary of MODIS L1B Products

ECS Short Name	Product Contents
MODIS/Terra(Aqua)	
MOD02QKM	Calibrated Earth View data at 250m resolution.
MOD02HKM	Calibrated Earth View data at 500m resolution, including the 250m resolution bands aggregated to appear at 500m resolution.
MOD021KM	Calibrated Earth View data at 1km resolution, including the 250m and 500m resolution bands aggregated to appear at 1km resolution.
MOD02OBC	On Board Calibrator (OBC) and Engineering Data.

<sup>+</sup> Corresponding author. Tel.: +86-27-68778392.  
E-mail address: [lmeng@whu.edu.cn](mailto:lmeng@whu.edu.cn).

Based on the points we are mentioned above, nowadays, MODIS L1B data are playing more important role in many domains, such as global resource, environment, climate change, water resources and so on. In this paper, we are focusing on automatic processing of MODIS L1B Data.

## 2. The MODIS L1B Data Automatic Processing System

In order to realize automatic processing of MODIS L1B Data, we design the MODIS L1B Data Automatic Processing System (MLDAPS). MLDAPS mainly has 4 layers in logic, receive layer, processing layer, storage layer and application layer. Figure 1 gives Hierarchy model of MLDAPS.

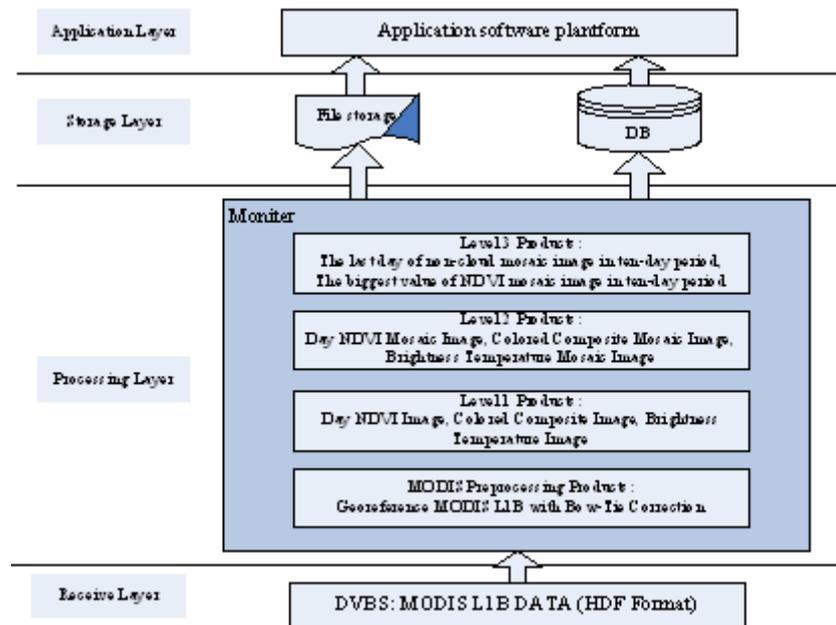


Fig.1: Hierarchy model of MLDAPS.

- Receive Layer: Receive MODIS L1B data by using DVB-S, formatted in HDF.
- Processing Layer: Through monitor procedures, realize automatic processing of MODIS L1B Data, generate four level products. They are MODIS Preprocessing Products, Level 1 Products, Level 2 Products, Level 3 Products.
- Storage Layer: Store the 4 level products both in file system and database.
- Application Layer: Integrate with the application systems for practical application need.

## 3. Realization of MLDAPS

In this section, we will describe realization of MLDAPS in detail. The main technology includes: ENVI/IDL, VS2005 C#, MRTSwath (MODIS Reprojection Tool Swath) created by USGS. There are four steps as follow.

### 3.1. The processing of MODIS L1B Preprocessing Products

In this part, BOW-TIE correction is required, its essential is the process of data format conversion (Swath to GRID). MLDAPS integrate the MRTSwath (MODIS Reprojection Tool Swath) to realize the correction which may be run from the command-line that allows background processing of large MODIS data files when the system load is light. Here is an example of calling a command-line interface in c#:

```
AppToolPro = new Process();
AppToolPro.StartInfo.FileName = "c:\MRTSwath\bin\swath2grid.exe";
AppToolPro.StartInfo.Arguments = "-pf=c:\template.prm" + "-if=c:\TERRA_2008_04_18_04_56_XJ.MOD02HKM.hdf" + "-gf=c:\TERRA_2008_04_18_04_56_XJ.MOD03.hdf" + "-of=d:\c:\TERRA_200804180456_XJ_MOD02HKM.tif" + "-sds=EV_500_RefSB;EV_250_Aggr500_RefSB";
AppToolPro.Start();
```

As Fig.2 below describes, the tool reproject the HDF-EOS file with bowtie correction and Geometric correction use the MOD03 (MODIS Geolocation) product. The results of the process are dataset of single band data. MLDAPS integrate these data of bands into one dataset by using the ENVI standard routines:

ENVI\_DOIT,'cf\_doit',dims=dims,fid=Fill\_fids,out\_dt=12,pos=pos,out\_name=out\_name

Calibration parameters are called reflectance\_scales and reflectance\_offsets, which are written as attributes to the reflective band dataset. The reflectance product is given by:

$$\rho \cos(\theta)_{B,T,FS} = reflectance\_scales_B (SI_{B,T,FS} - reflectance\_offsets_B)$$

Radiance is similar calculate from the equation:

$$L_{B,T,FS} = radiance\_scales_B (SI_{B,T,FS} - radiance\_offsets_B)$$

First obtain the Calibration parameters(reflectance and radiance) from each solar band of HDF-EOS files through HDF\_SD\_ATTRINFO IDL routine, then calculate the Reflectance and Radiance products with the Calibration parameters though GAINOFF\_DOIT routine to apply the gains and offsets.

To use some parameters of the products in the follow calculation and research, the metadata of the HDF-EOS files should be written in the level 1 products in XML format which is convenient to spread on the internet. The cloud coverage is the important information to write in XML which resulted from Cloud masking process by using detected expressions 'c1<0.2 or (c1-c18)/(c1+c18)<0' (where c1= Channel 1 of 1KM Reflectance SDS, c18 = Channel 18 of 1KM Reflectance SDS).

The data format of all the products should be converted to TIFF/GeoTIFF, and quicklook image related to GeoTIFF are JPEG format. All the products are stored in files and ORALCE DB.

MLDAPS build a secure log mechanism. During the process, three level logs monitor every step of the program. If there is an error occurring, program will catch the error and write it to error-logs, giving notice to administrator in several ways. But it will go on to deal with next data.

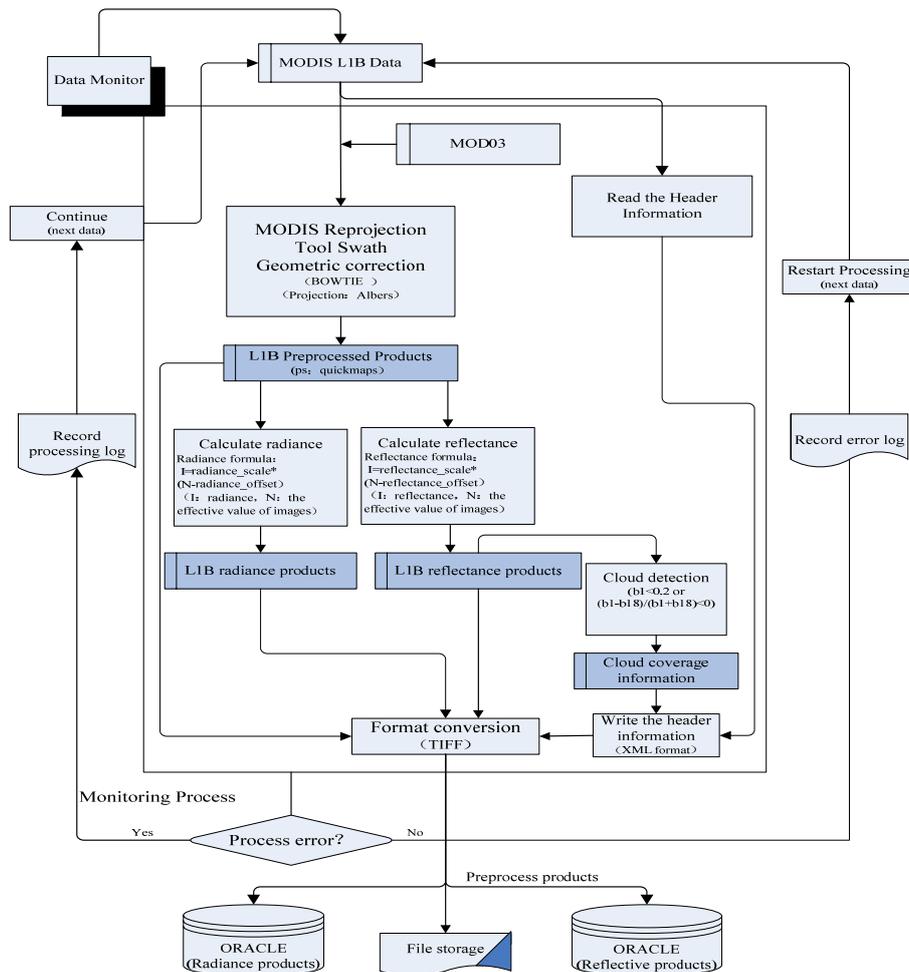


Fig.2 : L1B preprocess product processing

### 3.2. The processing of Level 1 products

Level 1 products include three types of products, Day NDVI (Normalized Difference Vegetation Index) Image, Day Colored composite Image and Day Brightness Temperature Image. Each product generation steps will be introduced as follows.

Fig 3. describes the work flow of the process:

(1) NDVI calculations are based on the principle that growing plants strongly absorb radiation in the visible region of the spectrum (PAR, or photosynthetically active radiation), while strongly reflecting radiation in the near infrared (NIR) region.

The NDVI for a pixel is calculated using the formula:

$$NDVI = \frac{ch2(PAR) - ch1(NIR)}{ch2(PAR) + ch1(NIR)}$$

Where ch1= channel 1 of 250m Reflectance Product, ch2= channel 2 of 250m Reflectance Product. Calling the ENVI routine “NDVI\_DOIT” in batch model to process the entire files in given directory:

ENVI\_DOIT,'NDVI\_DOIT',fid=fid,dims=dims,pos=[1,0],out\_name=out\_name

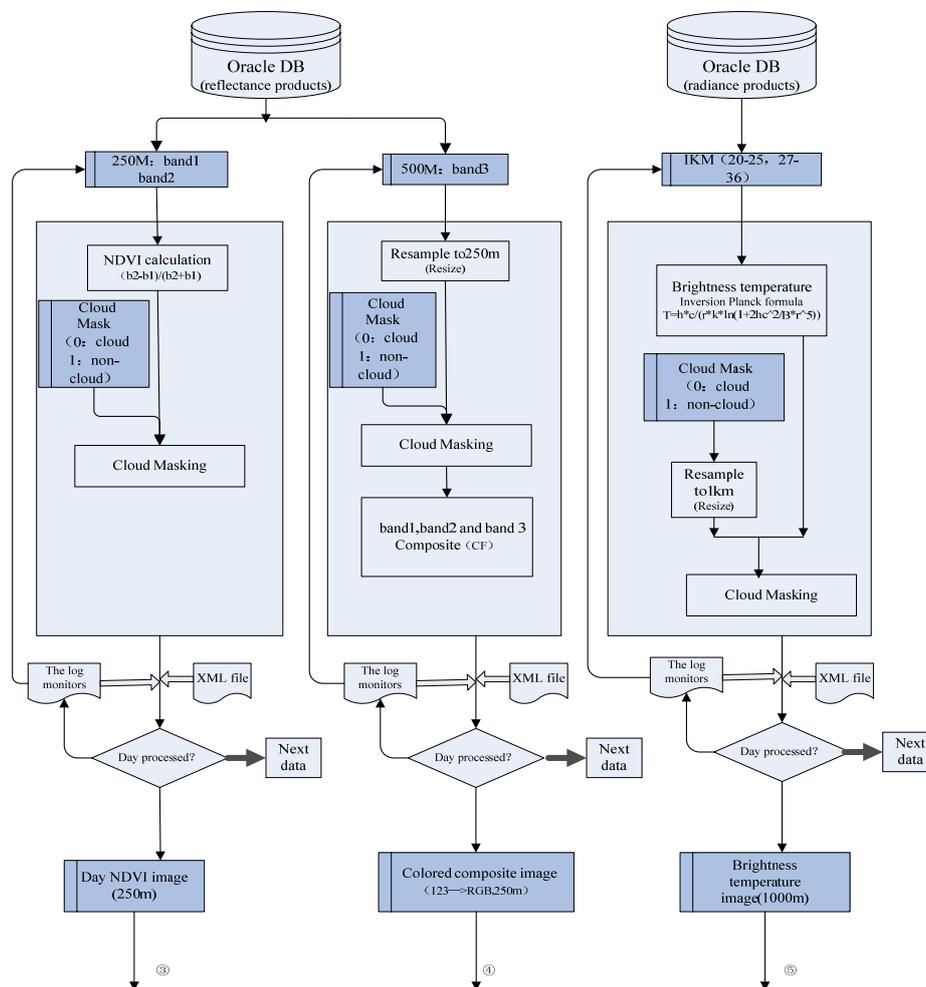


Fig.3 : Level 1 product processing

The calculate result is masked with the cloud mask of 250m resolution. The logs monitor the rate of progress. If the files of a day are all completed, the process will go to next day.

(2) Colored composition is the process of compositing band1, band2 of 250m of reflectance product and band3 of 500m reflectance product which should be resampled to 250m resolution to an RGB Image. According the “CF\_DOIT” ENVI routine, composition complete:

ENVI\_DOIT,'CF\_DOIT',fid=fid,dims=dims,pos=pos,out\_name=out\_name.

The composite result is masked with the cloud mask of 250m resolution. The logs do the same work as NDVI product logs; it will check whether the files of a day are all completed. If it is sure, the process will go to process data of next day.

(3) The Brightness temperature for a pixel is calculated using the formula as follows:

$$T = \frac{hc}{\lambda k \ln(1 + 2 \frac{hc^2}{B\lambda^5})}$$

(Planck's constant:  $h=6.6262 \times 10^{-34}JS$ , Boltzmann constant: $k=1.3846 \times 10^{-23}J/K$ , or  $5.669 \times 10^{-8}W/M^2K^4$ , The speed of light: $C=3 \times 10^8M/S$ )

Through the ENVI interface named "MATH\_DOIT", MLDAPS realizes the process in batch model:

ENVI\_DOIT,"MATH\_DOIT",exp='T=h\*c/(r\*k\*ln(1+2hc^2/B\*r^5))',fid=fid,dims=dims,pos=pos,out\_name=out\_name

The process data are all bands of 1km emissive products which are masked with the cloud mask of 1km resolution. The quicklook image and metadata are also saved as appendant to the three types of products in both file system and ORACLE DB. The three processes that realized by IDL program using the ENVI interface are independent so they can be running on parallel computers and use Multithread technology.

### 3.3. The processing of Level 2 Products

Level 2 products are generated from Level 1 products. It includes three types of products as follows.

Table 2: Level 2 Products List

Data Types	morning	afternoon	head-midnight	back-midnight
day NDVI mosaic-images	✓	✓		
colored composite mosaic-images	✓	✓		
bright temperature mosaic-images	✓	✓	✓	✓

(1) Day NDVI mosaic images

The day NDVI images will be classified according to time interval per six hours. The morning period is from six to twelve o'clock and the afternoon period is from twelve to eighteen o'clock. The morning NDVI images and the afternoon NDVI images are both mosaic together using the standard ENVI interface of the mosaic-doit routine. In order to get a clear mosaic image, we should follow the principles of lower cloud coverage and smaller cockeye angle. They can be found from the metadata file. The whole process is monitored and the system will create log files. If errors are encountered during processing, the log file will record these errors and the system will process the next data.

(2) Colored composite mosaic images

The colored composite images are also classified according to time interval per six hours. The morning colored composite images and the afternoon NDVI images are mosaic together using the standard ENVI interface of the mosaic-doit routine. The mosaic principles are the same as the day NDVI images. The whole process is similar to the process of day NDVI mosaic images.

(3) Brightness temperature mosaic images

The brightness temperature mosaic-images are also classified according to time interval per six hours. The only difference is that the brightness temperature images have four time intervals, including the morning, afternoon, head-midnight and back-midnight. Every time-interval images are mosaic as the above.

When all the images have been completed, four images will be generated. They are the morning mosaic-image, the afternoon mosaic-image, the head-midnight mosaic-image and the back-midnight mosaic-image.

All the result mosaic-images will be restored in Oracle Database and files. The attribute information of images is written to a file of xml format. Every mosaic-image has a quicklook image according to the image. The flowchart is as follows.

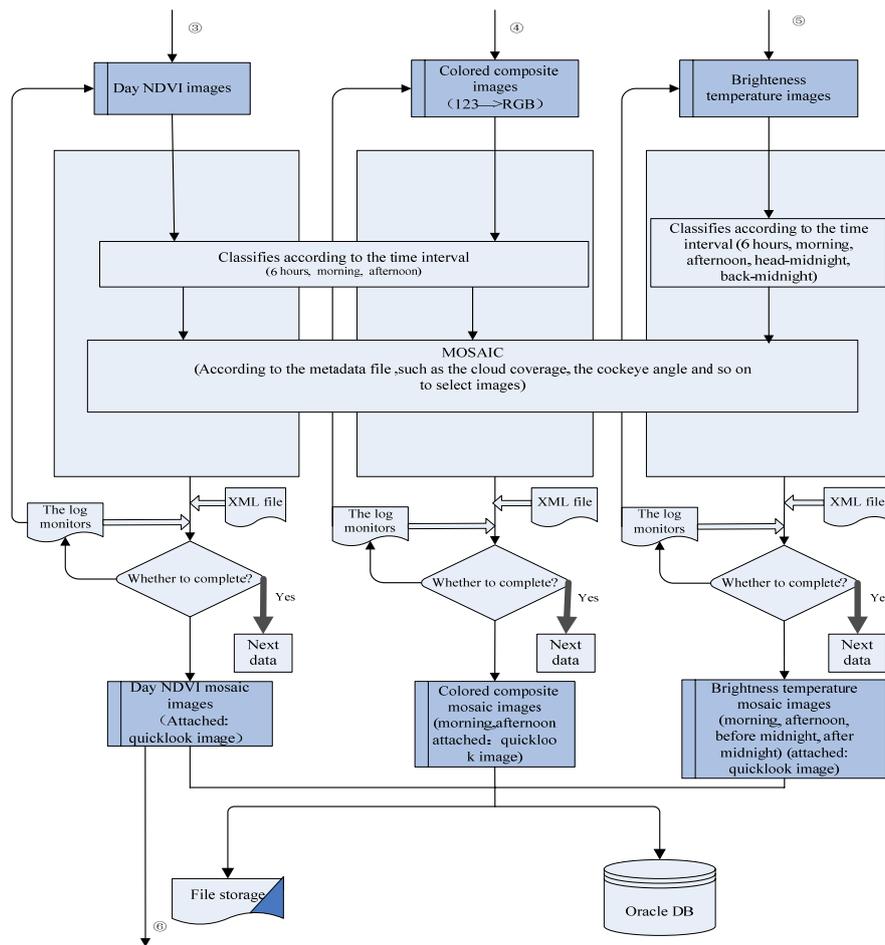


Fig.4 : Level 2 product processing

### 3.4. The processing of Level 3 Products

Level 3 Products are generated by day NDVI mosaic images of Level 2 Products. Level 3 Products have two types. One is non-cloud NDVI mosaic image of the latest day in ten-day period, the other is the biggest value of NDVI mosaic image in ten-day period. The flowchart is as follows, please see fig 5.

(1) non-cloud NDVI mosaic image of the last day in ten-day period

The day NDVI mosaic images are packed up per ten-day period. One month has three periods. They are upper ten-day, middle ten-day and lower ten-day. From the last day of the ten-day period to front, select the pixel whose value are not equal zero, and record the date of the pixel. Then put the pixel value to image template and put the date value to the data template. It is implemented by the standard ENVI interface of the math-doit routine. The Pseudo-code is as follows.

```

For i=n-1,0
  if p(i) not equal 0 p=p(i);
  break;
Endfor

```

When all the ten days NDVI images are processed completely, non-cloud mosaic image of latest day in ten-day period and the pixel date raster image are both generated..

(2) the biggest value of NDVI mosaic image in ten-day period

From the first day of the ten-day period to the last day, compare per pixel of the ten days images and choose the pixel whose value is the biggest, and record the date of the pixel. Then put the pixel value to image template and put the date value to the data template. It is implemented by the standard ENVI interface of the math-doit routine.

```

For i=0,n-1 p=max(p(i)).

```

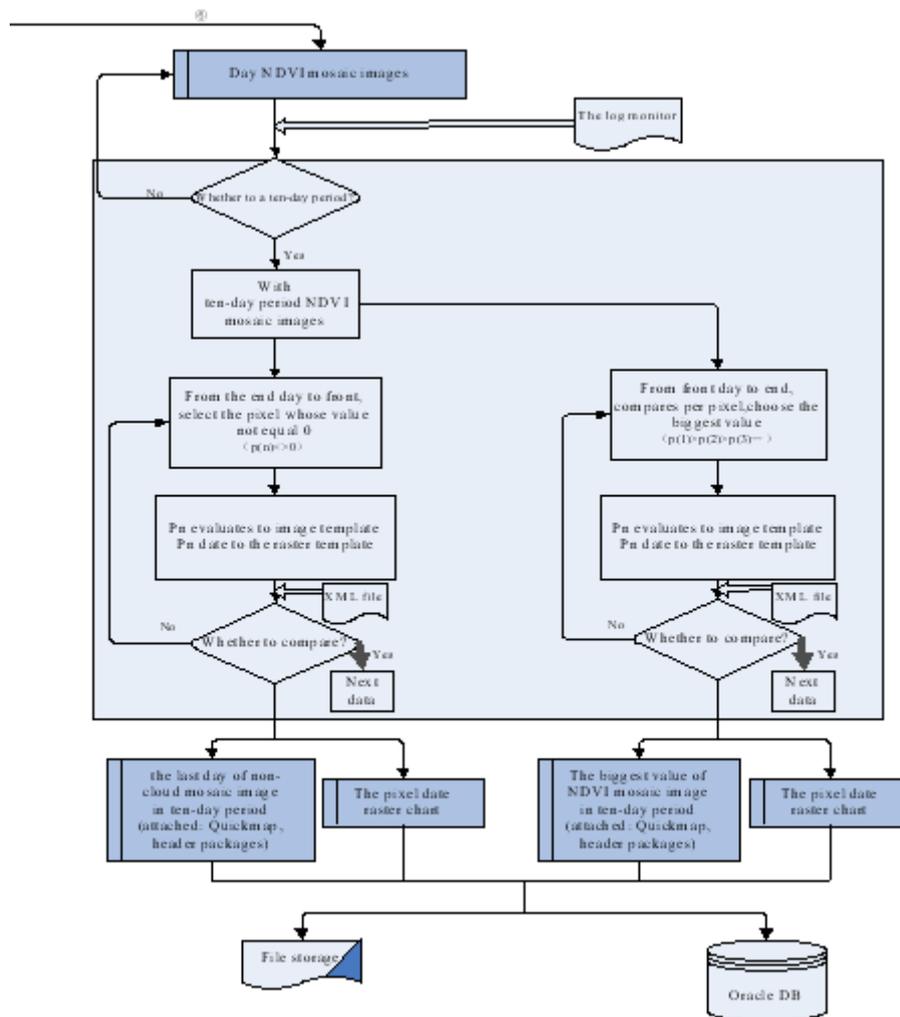


Fig.5 : Level 3 product processing

When all the ten days NDVI images are processed completely, the biggest value of NDVI mosaic-image in ten-day period and the pixel date raster image are generated.

All the result images will be restored in Oracle Database and files. The attribute information of images is written to a file of xml format. Every image has a quicklook image according to the image.

## 4. Spatial Accuracy Assessment

### 4.1. Validation in remote sensing

The quality of products in MLDAPS partly depends on the quality of MODIS L1B products. Generally, MODIS sensor calibration uncertainty is 2%. Spatial position error is 150 meters (15%) which is designed to images with the spatial resolution of 1K meters. By correcting with ground control points, its actual space position error is 50 meters (5%). Using the fixed offset calculation method, the space position error is 10% which is designed to images with the spatial resolution of 500 meters, and 20% to images with the spatial resolution of 250 meters. Meanwhile, because we use the data resample interpolation during the process, the error will not surpass the original error after the processing. Now, we will give a example.

We can see that MODIS L1B Preprocessing Product maintain the histogram pattern of MODIS L1B data in Fig.6. After processing the region of image extended, so the right vertical axis increased a number of pixels.

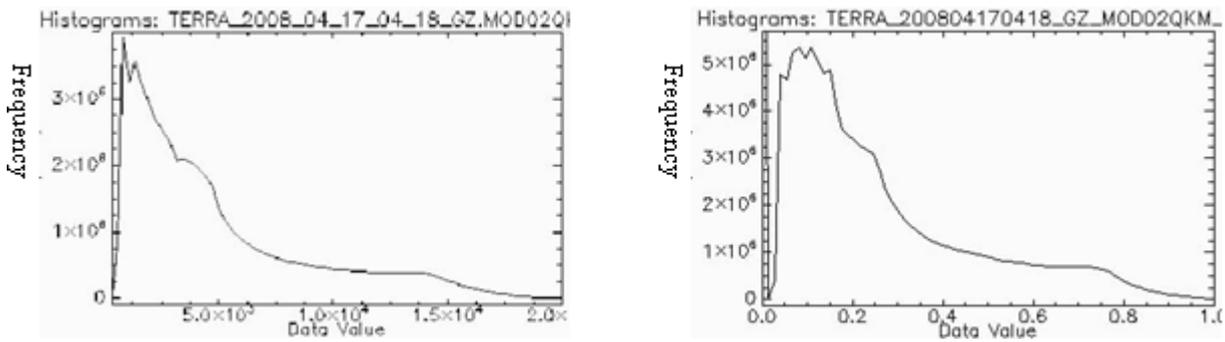


Fig.6 : MODIS L1B data (band2) compared with MODIS L1B Preprocessing Product (band2) in histogram

## 4.2. Spatial data conflation and information fusion

The products of MLDAPS can not only conflate with vector data, but also can fuse with raster data with high spatial resolution. It is a fact that the products have a very good integration with vector data and raster data. Please look at Fig.7 and Fig.8.



Fig.7: Products conflate with vector data



Fig.8 : Products fuse with ETM image

In Fig.7 we can clearly see that the MODIS L1B preprocessing product conflate with vector data of China's lake in good effect, offset several pixels at most. On the other hand, MODIS L1B preprocessing product, which has 250 meters spatial resolution, fuses with ETM image which has 15 meters spatial resolution in good result, offset several pixels at most. At the same time, we can get the same conclusion from table 2, because the root mean square (RMS) is too small to guarantee the quality of the products in MLDAPS.

Table 2. MODIS L1B preprocessing product to ETM image GCP List

	Base X	Base Y	Warp X	Warp Y	Predict X	Predict Y	Error X	Error Y	RMS
#1+	13790.00	27447.00	1868.00	1080.00	1868.0116	1079.9677	0.0116	-0.0323	0.0343
#2+	4278.25	28188.75	1314.00	1133.75	1314.0583	1133.5875	0.0583	-0.1625	0.1727
#3+	1467.75	21636.00	1143.25	765.50	1143.2413	765.5243	-0.0087	0.0243	0.0259
#4+	5015.25	30100.75	1361.00	1242.00	1360.9524	1242.1325	-0.0476	0.1325	0.1408
#5+	11801.00	25084.50	1731.25	945.00	1731.2364	945.0380	-0.0136	0.0380	0.0403

## 5. Conclusion

In order to implement automatic processing of MODIS L1B Data, we design MLDAPS that can run without people's operation. By using several advanced technology, we realize MLDAPS, the products after processing are very plentiful which can be used for different application demand and meet the requirements of data accuracy. In the future work, on one hand, we will improve the performance and efficiency of MLDAPS by using the grid technology to achieve the purpose of parallel computing. On the other hand, we will find a better use of data in application system.

## 6. Acknowledgements

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