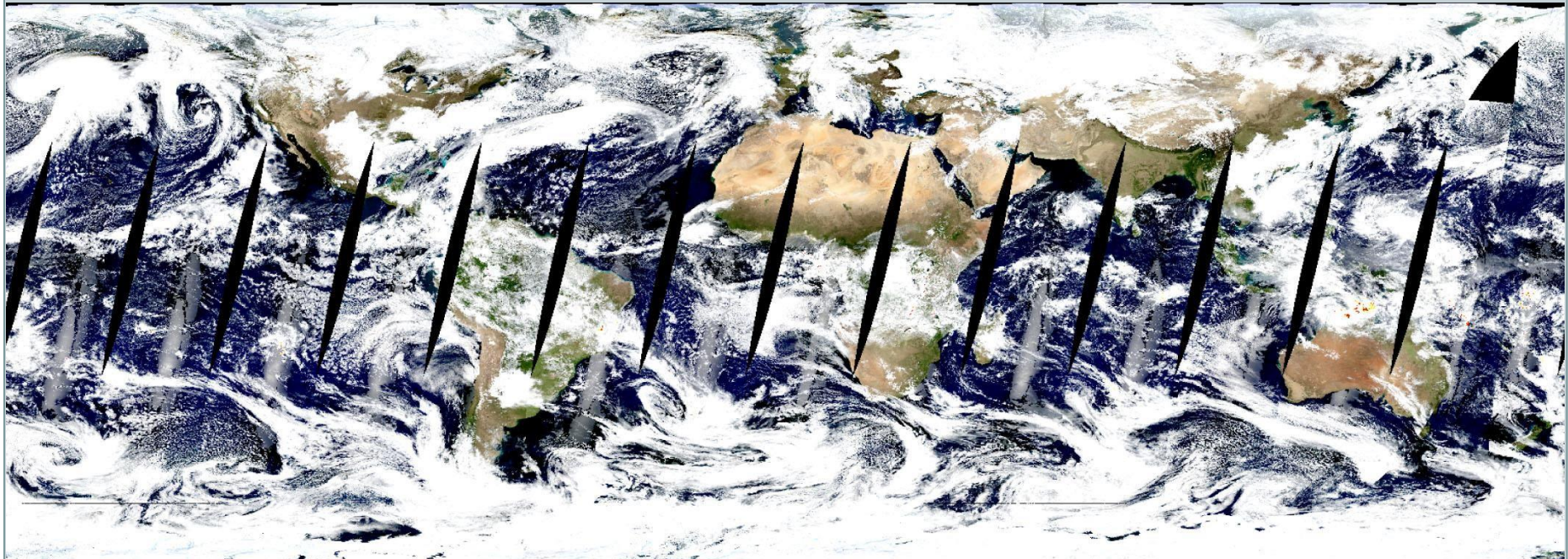


Lab 2

Crop mapping with MODIS imagery



November 26, 2023





Outline



- MODIS data download
- MOD09A1 data product pre-processing
- Vegetation index calculation
- Rice planting area mapping and acreage estimation





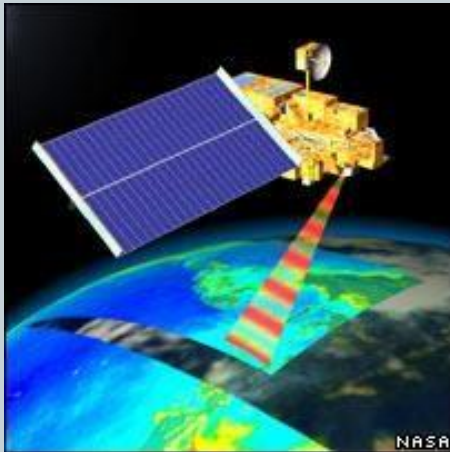
Why detect rice using MODIS data products?



- Regional-scale analyses of crop growth monitoring, productivity forecasting, and water resource management require updated maps of paddy rice fields.
- The MODIS instrument scans the entire surface of the Earth every one to two days.
- MODIS measures 36 spectral bands and it acquires data at three spatial resolutions: 250 m, 500 m, and 1 km.
- Above all, scholars can use nearly 20 years of MODIS imagery in archive.



Introduction to MODIS



MODIS: 2330 km
Landsat 8: 190 km

- Moderate Resolution Imaging Spectroradiometer
- Aboard the Terra (EOS AM, launched in 1999/12) and Aqua (EOS PM, launched in 2002/05) satellites
- Spatial resolution:
 - 250 m (bands 1-2)
 - 500 m (bands 3-7)
 - 1000 m (bands 8-36)
- Quantization: 12 bits
- Field of view: $\pm 55^\circ$
- Swath width: 2,330 km across-track



Review of MODIS band designations



Primary Use	Band	Bandwidth	Spectral Radiance	Required SNR
Land/Cloud/Aerosols Boundaries	1	620 - 670	21.8	128
	2	841 - 876	24.7	201
Land/Cloud/Aerosols Properties	3	459 - 479	35.3	243
	4	545 - 565	29.0	228
	5	1230 - 1250	5.4	74
	6	1628 - 1652	7.3	274
	7	2105 - 2155	1.0	110
Ocean Color/Phytoplankton/ Biogeochemistry	8	405 - 420	44.9	880
	9	438 - 448	41.9	838
	10	438 - 493	32.1	802
	11	526 - 536	27.9	754
	12	546 - 556	21.0	750
	13	662 - 672	9.5	910
	14	673 - 683	8.7	1087
	15	743 - 753	10.2	586
Atmospheric Water Vapor	16	862 - 877	6.2	516
	17	890 - 920	10.0	167
	18	931 - 941	3.6	57
	19	915 - 965	15.0	250

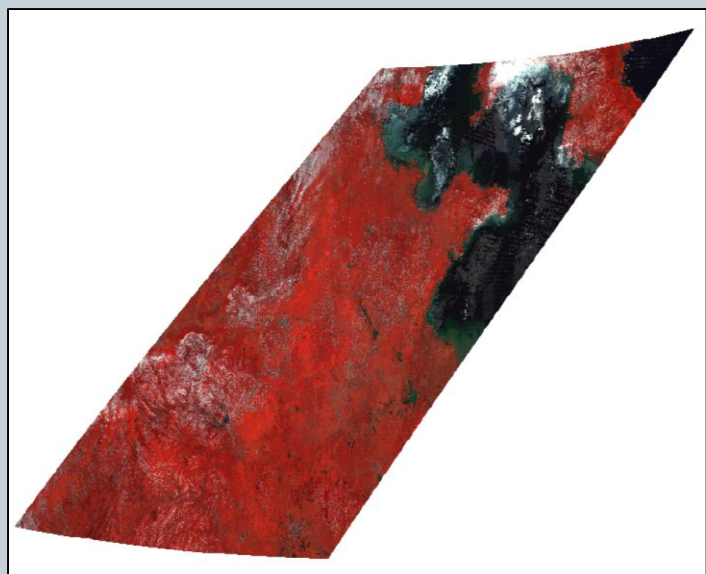
Primary Use	Band	Bandwidth	Spectral Radiance	Required NE[ΔT](K)
Surface/Cloud Temperature	20	3.660 - 3.840	0.45 (300K)	0.05
	21	3.929 - 3.989	2.38 (335K)	2.00
	22	3.929 - 3.989	0.67 (300K)	0.07
	23	4.020 - 4.080	0.79 (300K)	0.07
Atmospheric Temperature	24	4.433 - 4.498	0.17 (250K)	0.25
	25	4.482 - 4.549	0.59 (275K)	0.25
Cirrus Clouds Water Vapor	26	1.360 - 1.390	6.00	150(SNR)
	27	6.535 - 6.895	1.16 (240K)	0.25
	28	7.175 - 7.475	2.18 (250K)	0.25
Cloud Properties	29	8.400 - 8.700	9.58 (300K)	0.05
Ozone	30	9.580 - 9.880	3.69 (250K)	0.25
Surface/Cloud Temperature	31	10.780 - 11.280	9.55 (300K)	0.05
	32	11.770 - 12.270	8.94 (300K)	0.05
Cloud Top Altitude	33	13.185 - 13.485	4.52 (260K)	0.25
	34	13.485 - 13.785	3.76 (250K)	0.25
	35	13.785 - 14.085	3.11 (240K)	0.25
	36	14.085 - 14.385	2.08 (220K)	0.35



Test data: a tiled product MOD09A1



Filename **MOD09A1.A2021169.h27v05.061.2021178065421.hdf**



A false color composite (2-4-3)

Product info

- **Product name:** MOD09A1
- **Time of acquisition:** 2021-06-18
- **Data type** = “ MODIS/Terra Surface Reflectance 8-Day L3 Global 500m SIN Grid”

MODIS Naming Convention

- **MOD09A1** - Product Short Name
- **A2021169**- Julian Date of Acquisition (A- YYYYDDD)
- **h27v05** - Tile Identifier (horizontalXXverticalYY)
- **061** - Collection Version
- **2021178065421** - Julian Date of Production (YYYYDDDDHHMMSS)
- **.hdf** - Data Format (HDF-EOS)



Test data: a tiled product MOD09A1



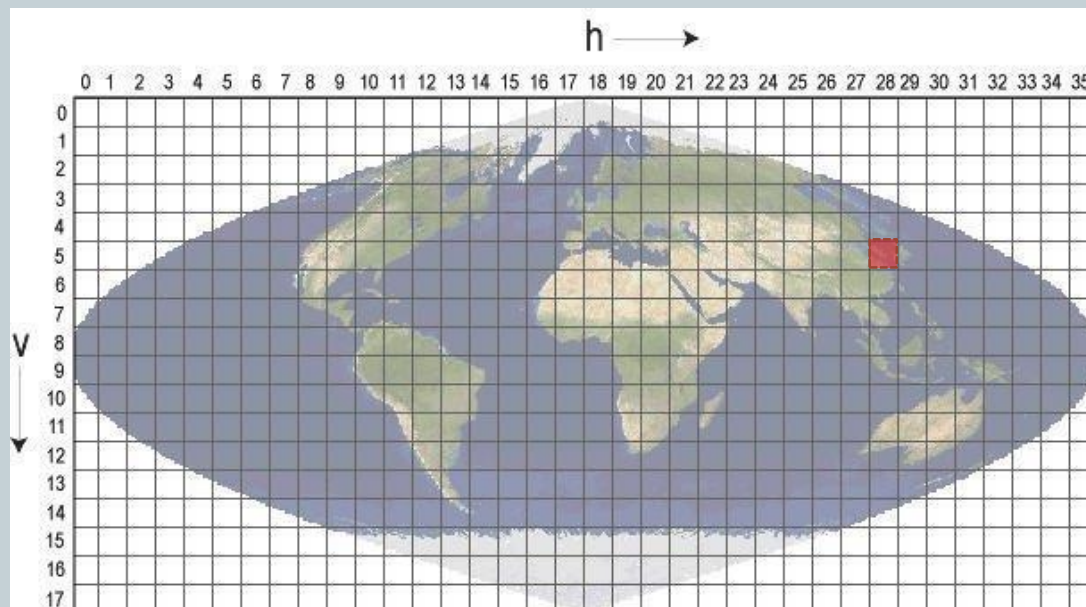
SDS Name	Description	Units	Data Type	Fill Value	No Data Value	Valid Range	Scale Factor
sur_refl_b01	Surface Reflectance Band 1 (620-670 nm)	N/A	16-bit signed integer	-28672	N/A	-100 to 16000	0.0001
sur_refl_b02	Surface Reflectance Band 2 (841-876 nm)	N/A	16-bit signed integer	-28672	N/A	-100 to 16000	0.0001
sur_refl_b03	Surface Reflectance Band 3 (459-479 nm)	N/A	16-bit signed integer	-28672	N/A	-100 to 16000	0.0001
sur_refl_b04	Surface Reflectance Band 4 (545-565 nm)	N/A	16-bit signed integer	-28672	N/A	-100 to 16000	0.0001
sur_refl_b05	Surface Reflectance Band 5 (1230-1250 nm)	N/A	16-bit signed integer	-28672	N/A	-100 to 16000	0.0001
sur_refl_b06	Surface Reflectance Band 6 (1628-1652 nm)	N/A	16-bit signed integer	-28672	N/A	-100 to 16000	0.0001
sur_refl_b07	Surface Reflectance Band 7 (2105-2155 nm)	N/A	16-bit signed integer	-28672	N/A	-100 to 16000	0.0001
sur_refl_qc_500m	Surface reflectance 500m band quality control flags	Bit Field	32-bit unsigned integer	4294967295	N/A	0 to 4294966531	N/A
sur_refl_szen	MODIS solar zenith angle	Degree	16-bit signed integer	0	N/A	0 to 18000	0.01
sur_refl_vzen	MODIS view zenith angle	Degree	16-bit signed integer	0	N/A	0 to 18000	0.01
sur_refl_raz	MODIS relative azimuth angle	Degree	16-bit signed integer	0	N/A	-18000 to 18000	0.01
sur_refl_state_500m	Surface reflectance 500m state flags	Bit Field	16-bit unsigned integer	65535	N/A	0 to 57343	N/A
sur_refl_day_of_year	Day of the year for the pixel	Julian day	16-bit unsigned integer	65535	N/A	1 to 366	N/A



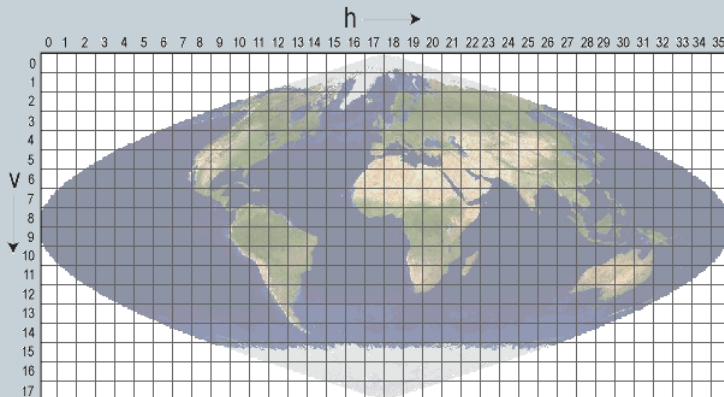
Sinusoidal grid tiling system



- Higher resolution MODIS land products (250 m, 500 m, 1 km) use the **Sinusoidal** projection system.
- To maintain reasonable file sizes, each projection is divided into a tiled grid.
- Tiles are $10^\circ \times 10^\circ$ at the equator.
- The globe is covered by 460 adjacent non-overlapping tiles.



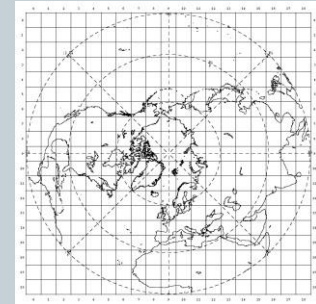
Projections for MODIS products



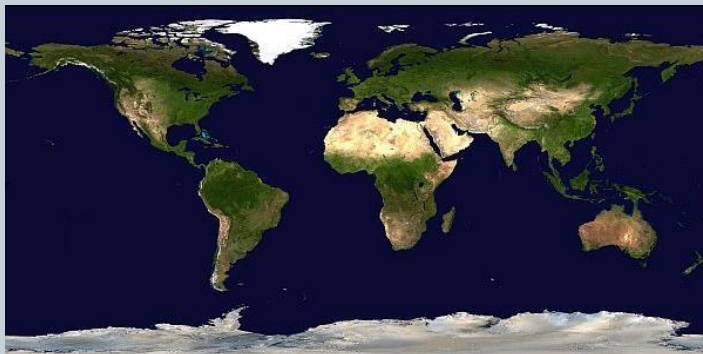
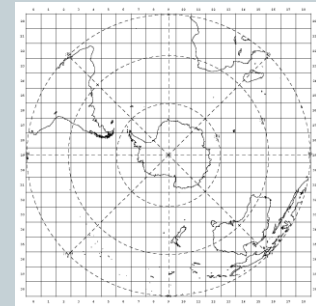
Sinusoidal Tile Grid

- Sinusoidal (SIN) projection
- 10° by 10° at the equator
- Used for land products at 250, 500 and 1000 m resolutions

North Pole



South Pole



Climate Modeling Grid (CMG)

- Geographic Lat/Lon projection
- Used for land projects at 0.05 degrees

Lambert Azimuthal Equal-Area Tile Grids (Polar)

- Lambert Azimuthal Equal Area projection
- Used only for sea ice products



What to do with this MOD09A1 tile ?



1. Image reprojection
2. Image displaying
3. Image stacking
4. Image cropping
5. Vegetation index calculation
6. Rice planting area extraction





How to reproject MOD09A1 by MRT?



- Install Java
- Record installation location

DIS > MODIS Reprojection Tool

搜索"MODIS Reprojection"

名称	修改日期	类型	大小
MRT_download_Win	2020/11/27 21:15	文件夹	
jdk-8u131-windows-x64.exe	2020/11/27 18:49	应用程序	202,784 KB
MRT_download_Win.zip	2020/11/27 18:48	压缩(zipped)文件...	7,020 KB
mrt41_usermanual_032811.pdf	2020/11/27 18:48	Adobe Acrobat ...	912 KB





How to reproject MOD09A1 by MRT?



- Create a new folder named MRT under the designated folder (e.g., `J:\Modis`). The software will be stored in that directory later.
- Double-click the `mrt_install.bat` file to install , then restart computer.

```
C:\WINDOWS\system32\cmd.exe

MODIS Reprojection Tool (MRT) Installation
-----

To install the Modis Reprojection Tool:

1. The unzip executable and the MRT_Win.zip installation zip file
   must be present in the current directory.
2. You must know the directory path where MRT is to be installed.
3. You must know the path to the Java bin directory on your system.

To determine the Java bin directory, click on the Windows Start button
and select Find, Files or Folders... Fill in the dialog box to search
all local hard drives for a file named java.exe. Make note of the
directory containing the most recent version of java.exe.
http://blog.csdn.net/gisboygogogo

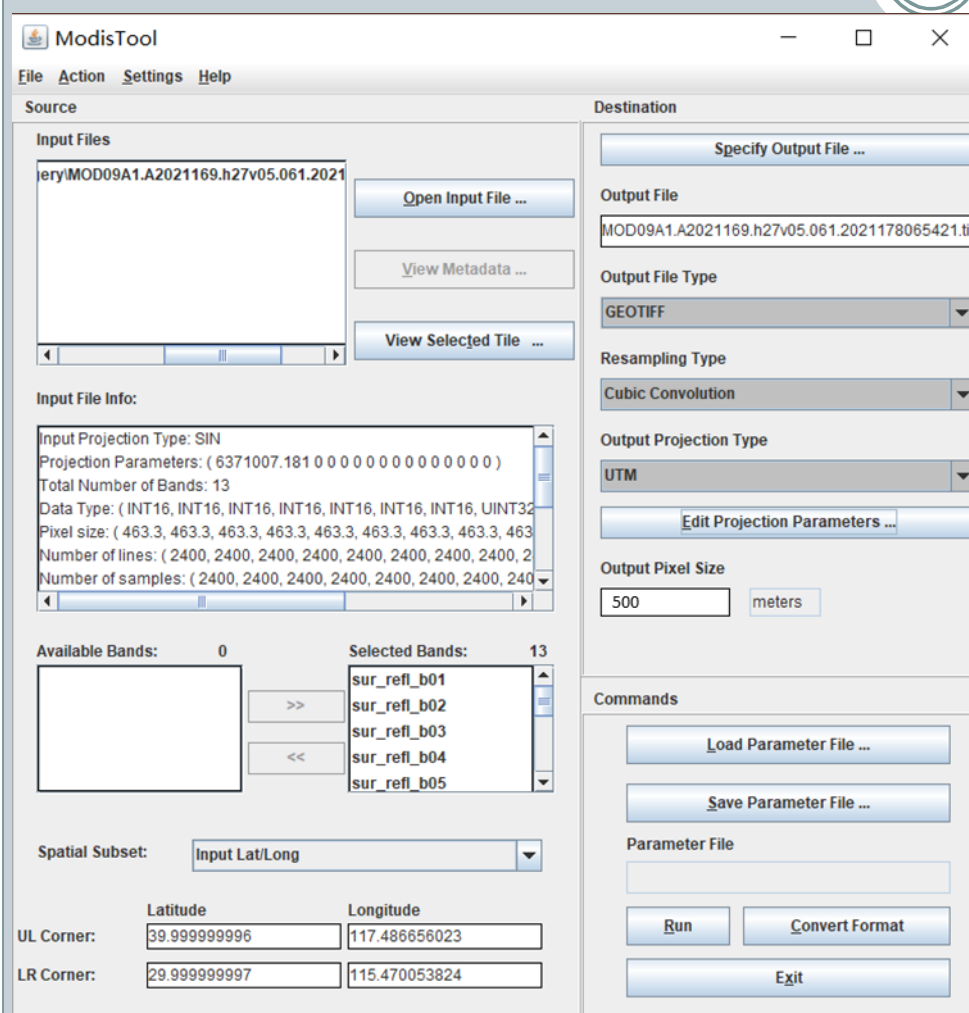
If java.exe does not appear in the Find Files listing, then Java may not be
installed on your system. You must install Java in order to run the MRT
GUI. Java software may be obtained on the World Wide Web at
http://java.sun.com.

请按任意键继续. . .
```





How to reproject MOD09A1 by MRT?

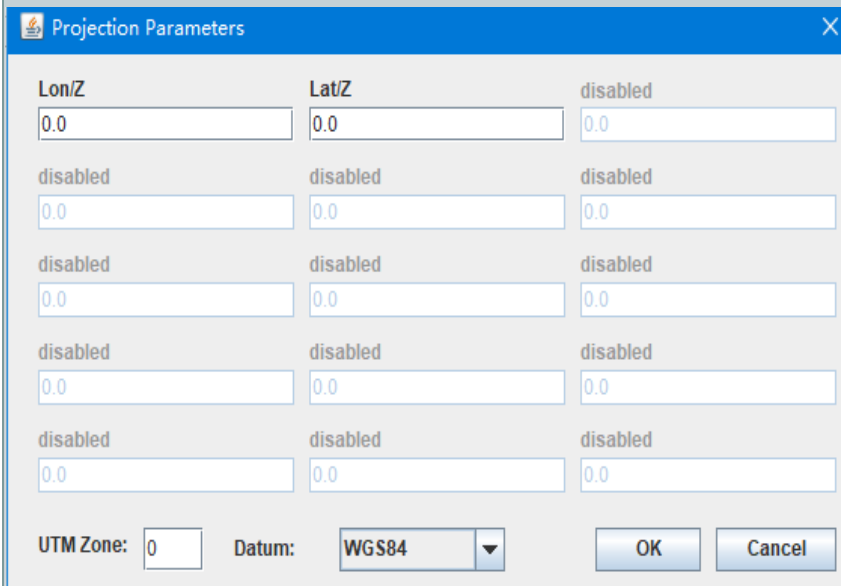


- Input MODIS data
- Selected Bands (sur_refl_b01...)
- Resampling type: cubic convolution
- Output file type: GEOTIF
- Output projection type: **UTM** (a commonly used projection)
- Edit Projection Parameters
- Click run



Projection parameters

- If Lon/Z and Lat/Z are zeros, we should set up the UTM Zone number.



Projection Parameters

Lon/Z	Lat/Z	disabled
0.0	0.0	0.0
disabled	disabled	disabled
0.0	0.0	0.0
disabled	disabled	disabled
0.0	0.0	0.0
disabled	disabled	disabled
0.0	0.0	0.0
disabled	disabled	disabled
0.0	0.0	0.0

UTM Zone: Datum:

Zone	Central meridian	Longitude range
43	75E	72-78E
44	81E	78-84E
45	87E	84-90E
46	93E	90-96E
47	99E	96-102E
48	105E	102-108E
49	111E	108-114E
50	117E	114-120E
51	123E	120-126E
52	129E	126-132E
53	135E	132-138E

Image layer stacking

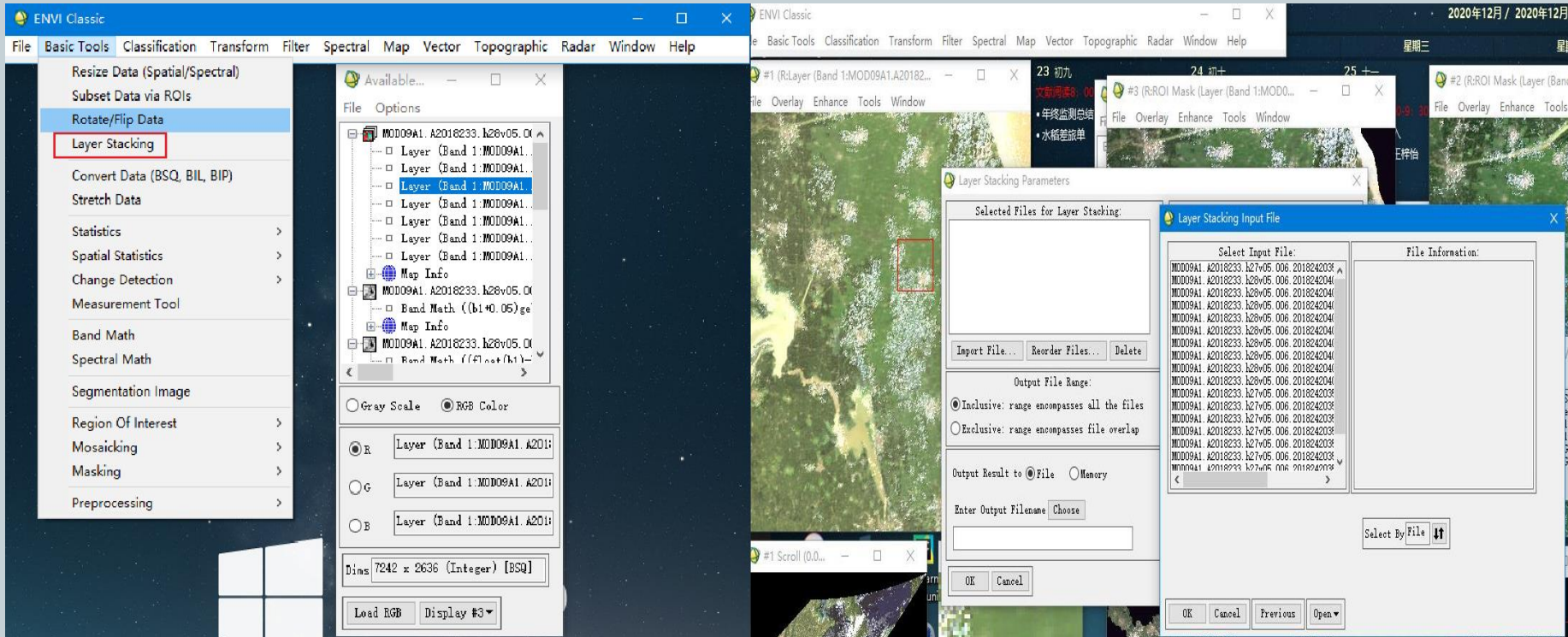


Image Cropping



Basic Tools -> Subset data via ROIs

SigmaPlot 12.0

Vector Window #1 : Cursor Query

File Mode Edit Options Help

32°23' 19.94"N, 119°2' 16.13"E Mode: Cursor Query
Active: "Layer: jiangsu.shp"

Spatial Subset via ROI Parameters

Select Input ROIs

EVT:Layer: jiangsu.shp

Number of items selected: 1

Select All Items Clear All Items

Mask pixels output of ROI ? Yes [↑↓]

Mask Background Value 0

Output Result to File Memory

Enter Output Filename Choose Compress

OK Queue Cancel

Available Vectors List

File Options

Available Vector Layers:

Layer: jiangsu.shp

Name: Layer: jiangsu.shp
File: J:\博士工作2020\农情遥感\others data\JS\
Size: 52,280 bytes
Records: 1 [3,149 nodes]
Proj : Geographic Lat/Lon [Degrees]
Datum: , DATUM[
Attributes: Yes

Select All Layers Deselect All Layers

Load Selected Remove Selected

Dims 7242 x 2636 (Integer) [BSQ]

Load RGB Display #3▼

Vegetation index calculation

Normalized Difference Vegetation Index (NDVI)

- Sensitive to vegetation greenness and biomass

Land Surface Water Index (LSWI)

- Sensitive to vegetation water content

Enhanced Vegetation Index (EVI)

- has improved sensitivity to high-biomass regions
- is less sensitive to canopy background and atmospheric influences

$$\text{NDVI} = \frac{\rho_{\text{NIR1}} - \rho_{\text{Red}}}{\rho_{\text{NIR1}} + \rho_{\text{Red}}} \quad (1)$$

$$\text{LSWI} = \frac{\rho_{\text{NIR1}} - \rho_{\text{SWIR1}}}{\rho_{\text{NIR1}} + \rho_{\text{SWIR1}}} \quad (2)$$

$$\text{EVI} = 2.5 \times \frac{\rho_{\text{NIR1}} - \rho_{\text{red}}}{\rho_{\text{NIR1}} + 6.0\rho_{\text{red}} - 7.5\rho_{\text{blue}} + 1} \quad (3)$$

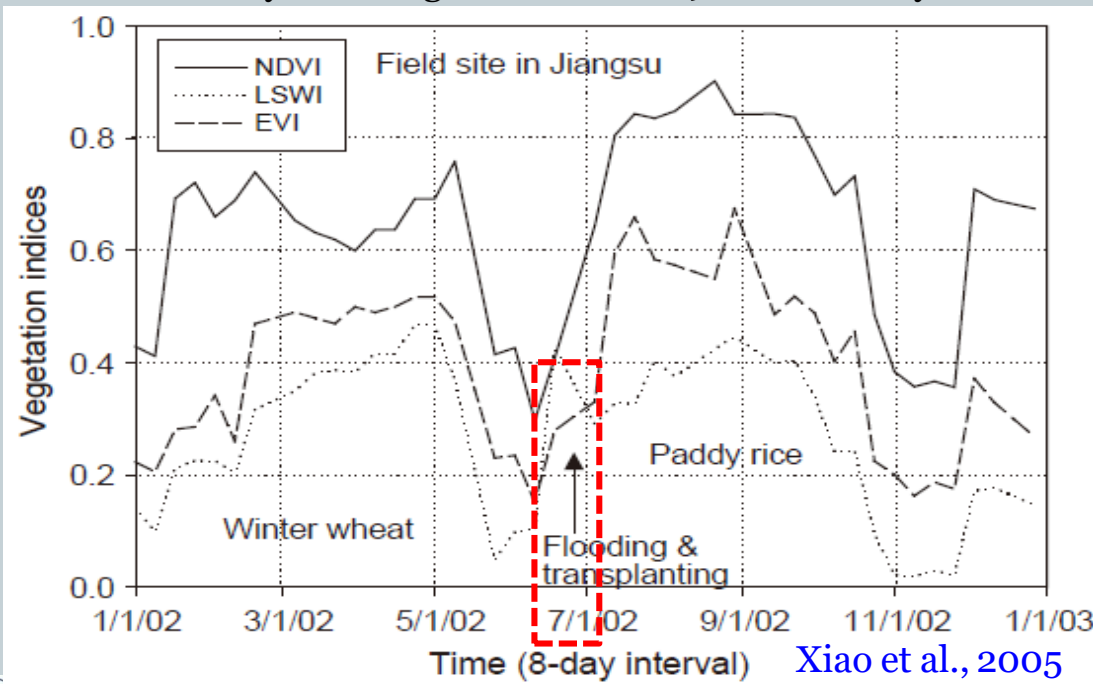
Notes: The ranges and spatial resolution of the 7 bands are listed as follows: Band 1 (red: 620~670 nm), Band 2 (NIR1: 841~876 nm), Band 3 (blue: 459~479 nm), Band 4 (green: 545~565 nm), Band 5 (NIR2: 1230~1250 nm), Band 6 (SWIR1: 1628~1652 nm), and Band 7 (SWIR2: 2105~2155 nm).

Paddy rice planting area extraction



- Thresholds for extracting the rice planting area from MODIS imagery:
① $LSWI > 0.12$, ② $EVI \text{ (or NDVI)} < 0.26$ and ③ $LSWI + 0.05 \geq EVI \text{ (or NDVI)}$
(Xiao et al,2005; Sun et al,2009; Feng et al,2019)

Only one image of DOY 160-190 is necessary.



Transplanting period across Jiangsu:

- From mid-June to early July (DOY 160-190)



MODIS download



- Search and Bulk-Download Data-EarthData

<https://search.earthdata.nasa.gov/>

- Browse and Download Data – LAADS DAAC

<https://ladsweb.modaps.eosdis.nasa.gov/search/>

- More information at <https://lpdaac.usgs.gov/products/mod09a1v006/>





Notes



Things to prepare:

- An Earthdata account
- Stable internet connection

General Steps:

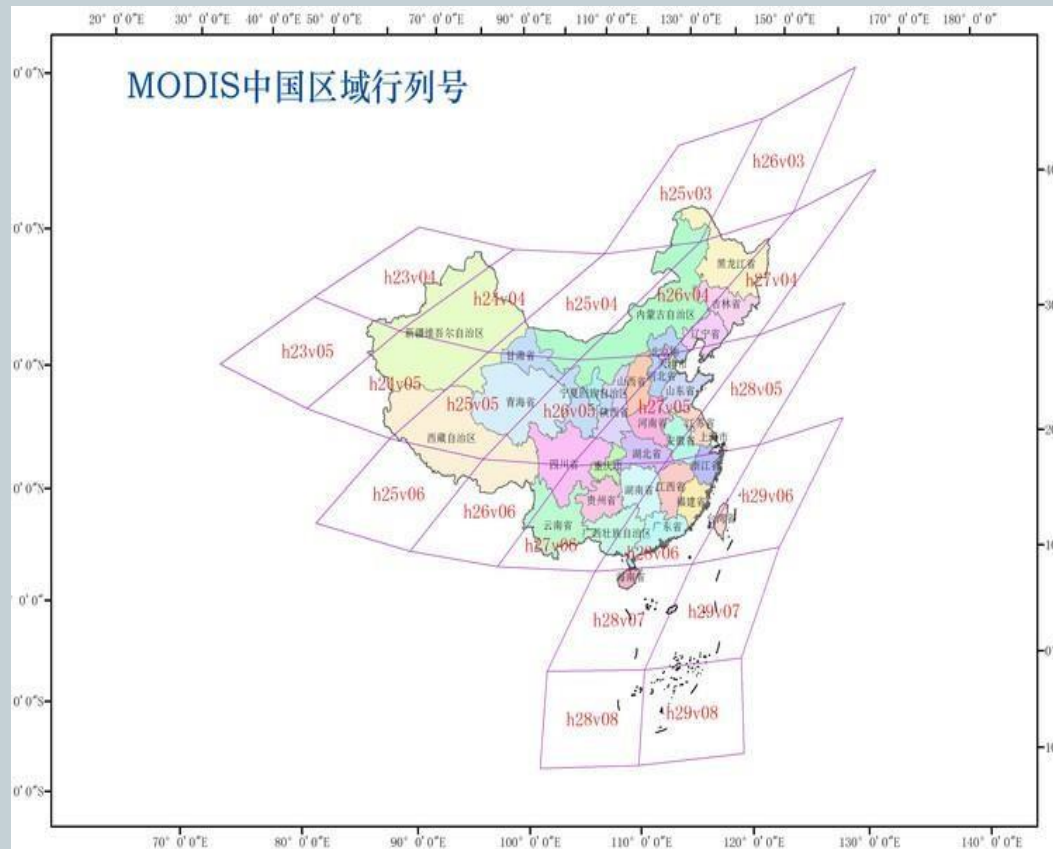
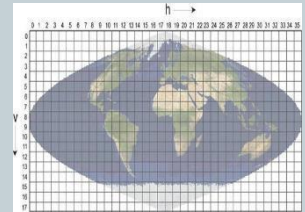
- Registration for Earthdata
- Log in
- Set up parameters to search data
- Search data
- Check results and select data
- Order data (free)
- Download



Notes



MODIS tile numbers for China region





Download MODIS images



The screenshot shows the NASA LAADS DAAC search interface. The top navigation bar includes 'PRODUCTS', 'TIME', 'LOCATION', 'FILES', and 'REVIEW & ORDER'. The search criteria are: 'No products selected', 'No date selected', 'W: -180°, N: 90°, E: 180°, S: -90°', and 'No files selected'. The search results are filtered by 'MODIS:Terra' and 'Land Surface Reflectance'. The left sidebar shows a list of categories, with 'Land Surface Reflectance [7]' selected. The main content area displays a list of products, with 'MOD09A1' highlighted. The footer includes the NASA logo, 'Level-1 and Atmosphere Archive & Distribution System', and 'Privacy Policy and Important Notices'.

Search Criteria:

- 1 PRODUCTS: No products selected
- 2 TIME: No date selected
- 3 LOCATION: W: -180°, N: 90°, E: 180°, S: -90°
- 4 FILES: No files selected
- 5 REVIEW & ORDER

Search Results:

- MODIS Collection 6.1 - Level 1, Atmosphere, Land (Archive Set 61)
- Land Surface Reflectance
- MODIS Collection 6.1 - Level 1, Atmosphere, Land (Archive Set 61)

Filters:

- MODIS:Terra
- Land Surface Reflectance [7]

Product List:

- MOD09: MODIS/Terra Atmospherically Corrected Surface Reflectance 5-Min L2 Swath 250m, 500m, 1km
- MOD09A1: MODIS/Terra Surface Reflectance 8-Day L3 Global 500m SIN Grid**
- MOD09CMA: MODIS/Terra Aerosol Optical Thickness Daily L3 Global 0.05Deg CMA
- MOD09CMG: MODIS/Terra Surface Reflectance Daily L3 Global 0.05Deg CMG
- MOD09GA: MODIS/Terra Surface Reflectance Daily L2G Global 1km and 500m SIN Grid
- MOD09GQ: MODIS/Terra Surface Reflectance Daily L2G Global 250m SIN Grid
- MOD09Q1: MODIS/Terra Surface Reflectance 8-Day L3 Global 250m SIN Grid





Download MODIS images

NASA LAADS DAAC About LAADS Data Learn Login

1 PRODUCTS 2 TIME 3 LOCATION 4 FILES 5 REVIEW & ORDER

MOD09A1 (61) 06/01/2021 .. 07/01/2021 2 locations selected 3 files selected reset

* Download selected files as json or csv

Search: Select All Clear All Query Results Selected (3) Images

Filename	Product (collection)	Image	Date / Time	Download
MOD09A1.A2021145.h28v05.061.2021154061058.hdf	MOD09A1 (61)		05/25/2021 00:00:00	59 MB
MOD09A1.A2021145.h27v05.061.2021154062041.hdf	MOD09A1 (61)		05/25/2021 00:00:00	67 MB
MOD09A1.A2021153.h28v05.061.2021162055728.hdf	MOD09A1 (61)		06/02/2021 00:00:00	60 MB
MOD09A1.A2021153.h27v05.061.2021162062028.hdf	MOD09A1 (61)		06/02/2021 00:00:00	68 MB
MOD09A1.A2021161.h27v05.061.2021170045857.hdf	MOD09A1 (61)		06/10/2021 00:00:00	73 MB
MOD09A1.A2021161.h28v05.061.2021170051917.hdf	MOD09A1 (61)		06/10/2021 00:00:00	68 MB
MOD09A1.A2021169.h28v05.061.2021178064757.hdf	MOD09A1 (61)		06/18/2021 00:00:00	69 MB
MOD09A1.A2021169.h27v05.061.2021178065421.hdf	MOD09A1 (61)		06/18/2021 00:00:00	66 MB
MOD09A1.A2021177.h28v05.061.2021188183934.hdf	MOD09A1 (61)		06/26/2021 00:00:00	73 MB
MOD09A1.A2021177.h27v05.061.2021188185949.hdf	MOD09A1 (61)		06/26/2021 00:00:00	71 MB

Previous 1 Next





Lab project



- **Assignments (60%):**

1. **Image downloading.** Download one cloudless tile of MOD09A1 from the transplanting period between **2018-2023**. The tile should cover one of the three rice production cities in Jiangsu (Suqian: h27v05, Taizhou: h28v05, & Huai'an: h27v05).
2. **Reprojection.** Using MRT to reproject the MOD09A1 images. And the new projection must be UTM.
3. **Layer stacking.** Stack up the seven multispectral bands by wavelength and generate a seven- band image file. Save this file in ENVI Standard format. **(1 × 2 files)**





Lab project



- **Assignments (60%):**

4. **Image cropping.** Crop the seven-band file with the city boundary (shapefile). Save this seven-band subset image file in ENVI Standard format. (1 × 2 files)
5. **Calculation of vegetation indices.** Derive NDVI, EVI and LSWI from each MODIS subset image. (3 × 2 files)
6. **Rice map creation.** Make a map of paddy rice planting area. (1 JPEG file + 1 pair of .dat & .hdr files)





Lab project



- **Answer questions(40%):**

1. Derive the rice planting area (in km²) in your selected municipality. Calculate the difference between your result and government statistics data relative to the government reported value ($100\% \times \text{diff}/\text{stats}$). (20%)
2. What could be the main sources of error that affect the accuracy of area estimation? Why? What do you think is worth investigation in the future to further improve the accuracy? (20%)



Procedures

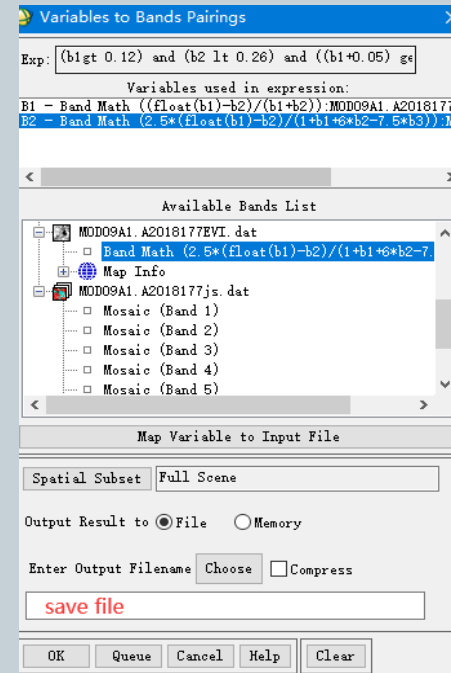
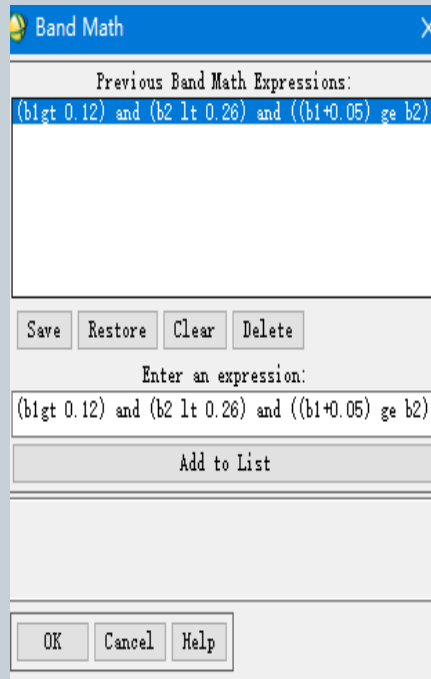


- **Image download:**
 - One MOD09A1 Image should be download from the LAADS DAAC
- **Image projection:**
 - Following the step of MRT
- **Image stacking:**
 - Basic Tools->layer stacking
- **Image cropping:**
 - Basic Tools->Subset data via ROIs
- **Calculation of vegetation indices:**
 - Basic Tools->Band math

Procedures



- **Rice map creation:**
 - Basic Tools->Band math

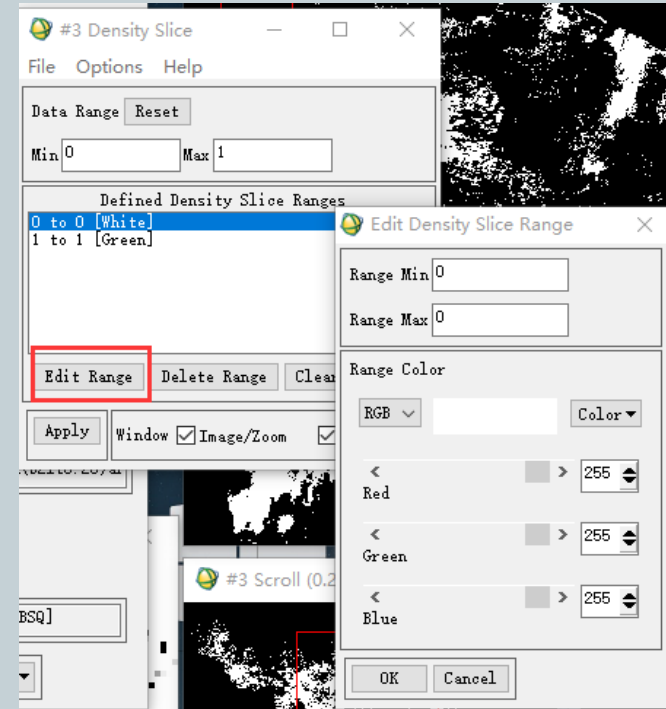
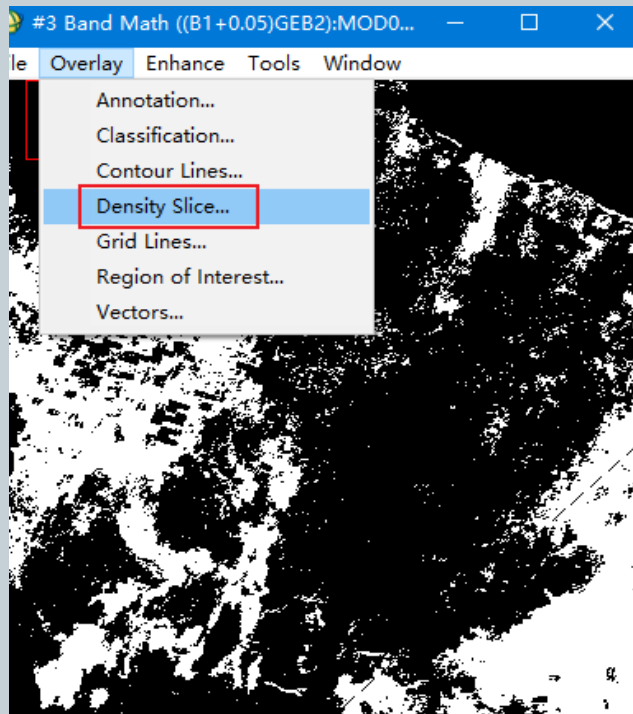


This formulas are $LSWI > 0.12$, $EVI < 0.26$ and $LSWI + 0.05 \geq EVI$
B1 is $LSWI$, B2 is EVI .

Procedures

● Map rice:

- Load display the file
- Overlay->Density slice
- File-> save image file -> image file

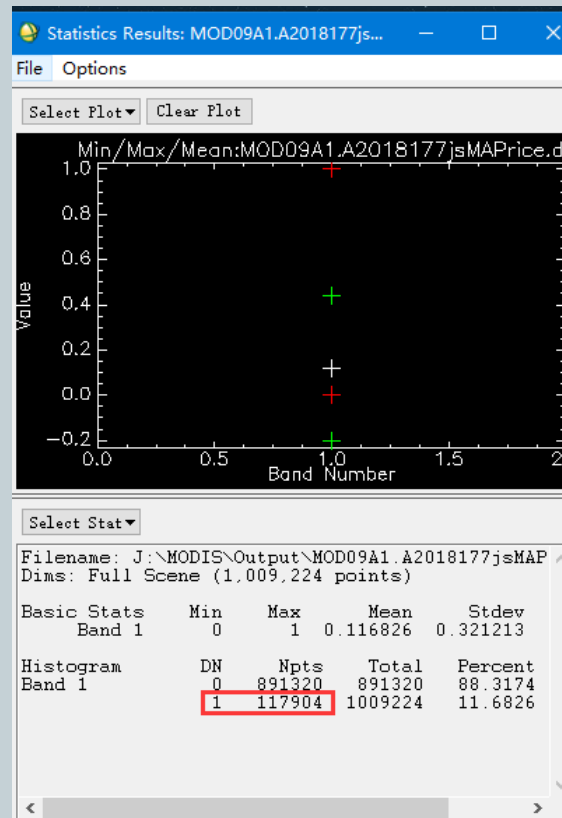
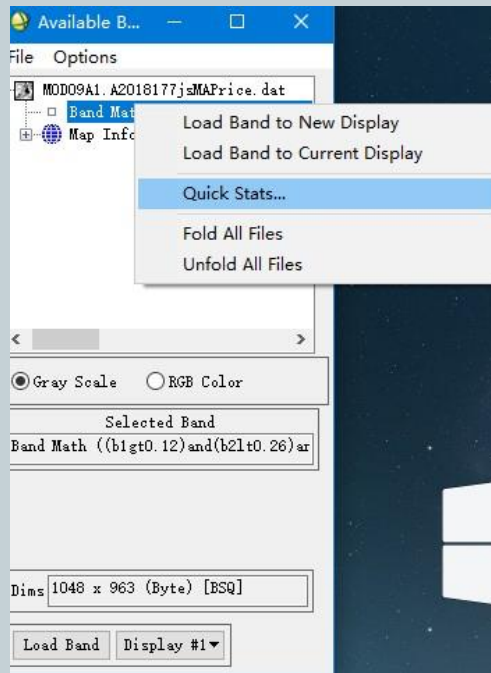


Make the (0 to 0) white color, then click Apply

Procedures



- **Calculation of rice planting area:**
 - Right click on map file->Quick stats...



Check the number of pixels with DN = 1.

Then Jiangsu rice area is
 $117904 * 0.500 * 0.500$
 $= 29476 \text{ km}^2$