# Application of FY data in global agriculture

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# Outline

- **overview**
- **FY-3 products related to global agriculture remote sensing**
- **Application of FY data in global agriculture**
- **summary**

# overview

- Agricultural monitoring is  to monitor and analyze the quantity, quality and utilization of cultivated land or grassland, and other information such as the area, growth, disaster and yield of main crops.
- It is of great significance to help governments to make scientific food policies, adjust  planting structure reasonably and guarantee  world food security.

**Traditional mode**

advantages：  accurate
disadvantages ：
Long cycle and slow update,
Poor representativeness of region situation,
high cost

effective supplement to the traditional methods

gradually become the main way of agricultural monitoring.

**Remote sensing monitoring**

advantages ：
high efficiency and fast update
large observing area
ability to represent the regional situation.
low cost

# overview

**demands**

many observation elements.

simultaneous observation is emphasized

high time resolution

large observation width to ensures the rapid repetition of coverage.

the spectral bands include red edge or short wave infrared spectral segments.

**features**

High time resolution, large-scale observation area , multichannel data

Parameters related to agricultural monitoring （NDVI、SM、LST、LAI)

temporal datasets

Agricultural remote sensing  is an important application field of FY -3 satellite

# overview--Application field in agricultural remote sensing

## Crop planting area and mapping

- crop planting area is an important basis for the national food policy and economic plan. It is necessary to  acquire  the area Quickly and accurately.

## crop growth monitoring

- monitoring indicators of crop growth mainly include VI, LAI and biomass. VI is the most widely used.

## crop yield estimation

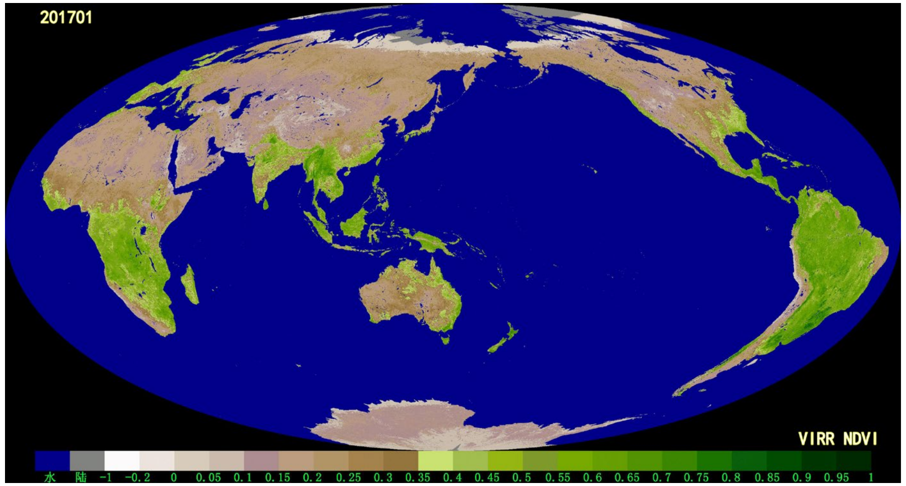
- three models of crop yield estimation of remote sensing：empirical model, semi mechanism model and mechanism model.

## agricultural disaster monitoring

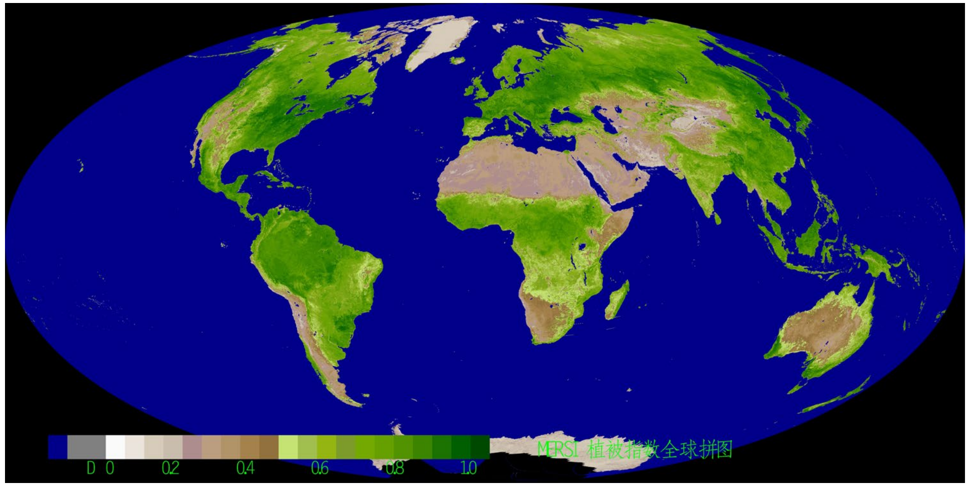
- drought, flood, low temperature freezing and disease remote sensing has developed to meet the needs of global and regional scale agricultural information acquisition.

# FY-3 products related to global agriculture monitoring--NDVI

## FY-3B/VIRR NDVI




## FY-3D/MERSI NDVI




## FY-3B VI specification list

| name | projection | coverage | Spatial resolution | frequency | |
|---|---|---|---|---|---|
| NDVI 10-day product | Hammer | Global(10°* 10°) | 1km | Ten days monthly | 2011.6-present |
| NDVI monthly product | Hammer | Global(10°*10°) | 250m | Ten days monthly | 2011.6-present |

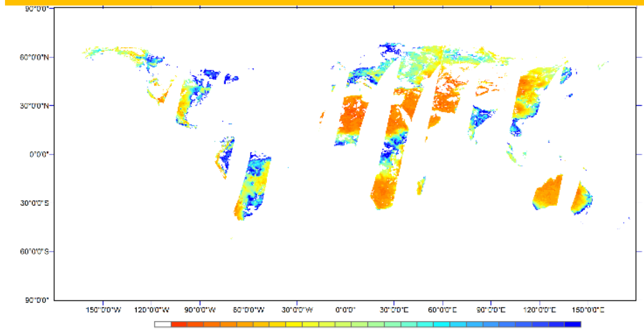
## FY-3D VI specification list

| Product name | projection | coverage | Spatial resolution | frequency |
|---|---|---|---|---|
| NDVI segment product | —— | 5-minute segment | 250m | 5 minutes |
| NDVI daily product | Geographic projection | global | 5km | daily |
| | Hammer | | 250m | |
| NDVI 10-day product | Geographic projection | global | 5km | Ten days |
| | Hammer | | 1km | |
| | Hammer | | 250m | |
| NDVI monthly product | Geographic projection | global | 5km | monthly |
| | Hammer | | 1km | |

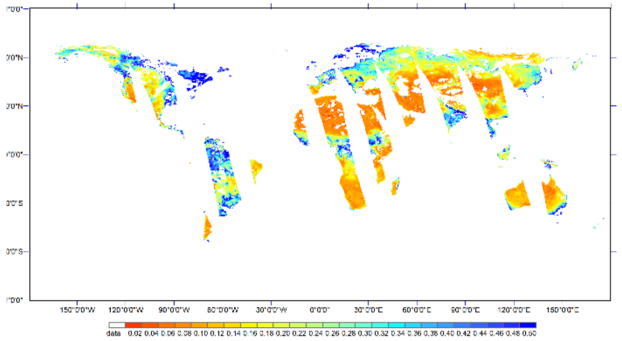
Zhang Liyang

# FY-3 products related to global agriculture monitoring- ---Soil Moisture

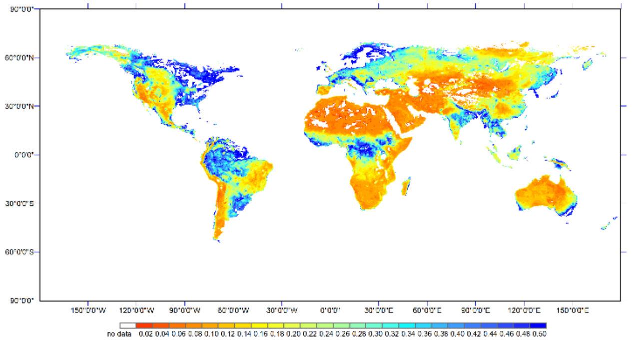
FY-3D/MWRI daily soil moisture(Descending)



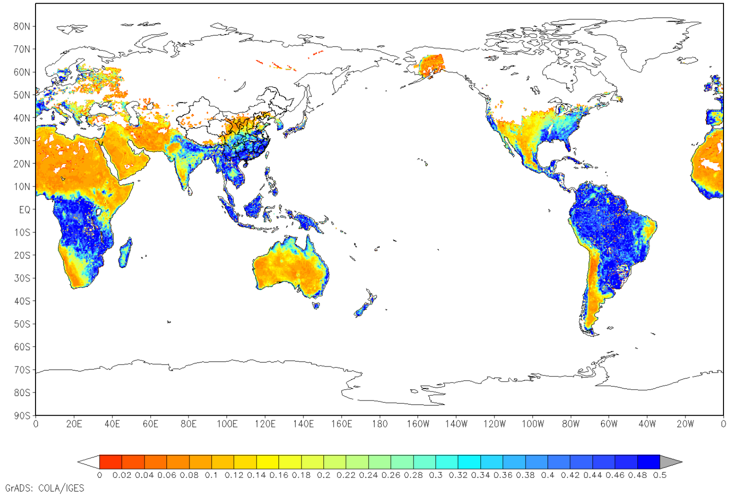
FY-3D/MWRI daily soil moisture(Ascending)



FY-3D/MWRI 10-day soil moisture



FY-3B/MWRI 10-day soil moisture

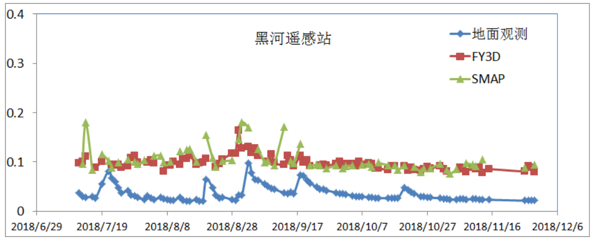


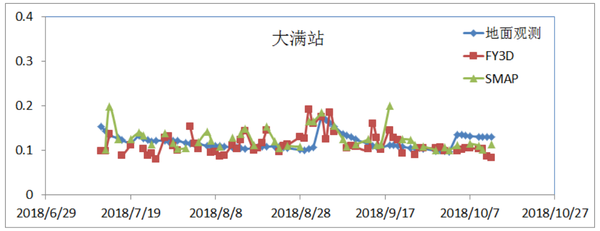

**FY3D/MWRI daily SM vs SMAP L3SMP daily SM （May,2019）**

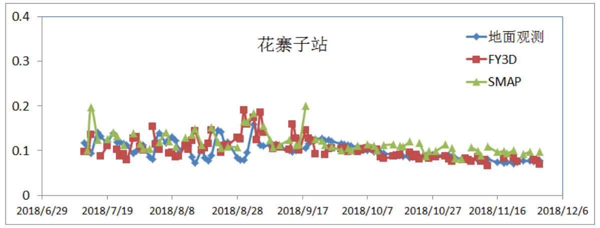
| all | | Sparse shrub | | Grassland | | Bare land | |
|---|---|---|---|---|---|---|---|
| Cor coe | RMSE | Cor coe | RMSE | Cor coe | RMSE | Cor coe | RMSE |
| 0.702 | 0.0624 | 0.785 | 0.0651 | 0.726 | **0.0667** | 0.521 | 0.035 |

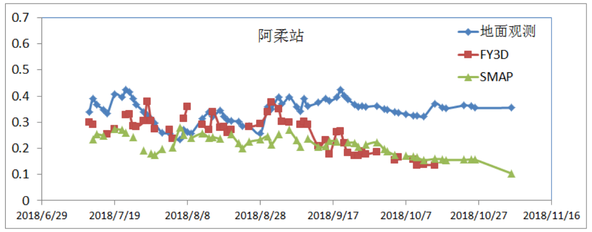
| RMSE | Heihe Station | Daman Station | Huazhaizi station | Arou Station |
|---|---|---|---|---|
| Ground vs FY3D | 0.0641 | 0.0277 | 0.0282 | 0.1198 |
| Ground vs SMAP | 0.0722 | 0.0266 | 0.0309 | 0.1414 |
| FY3D vs SMAP | 0.0204 | 0.0201 | 0.0215 | 0.0628 |

**FY3D/MWRI daily SM ,SMAP L3SMP daily SM, Ground Station SM (2018.7.12-2018.11)**



# Application in Global Agriculture Monitoring Using FY Data

- Staple Crop area extraction
- Phenology monitoring
- Global major crop growth monitoring
- Drought monitoring

# Application 1----- Staple Crop Area Extraction

✓**Macro distribution of crops**

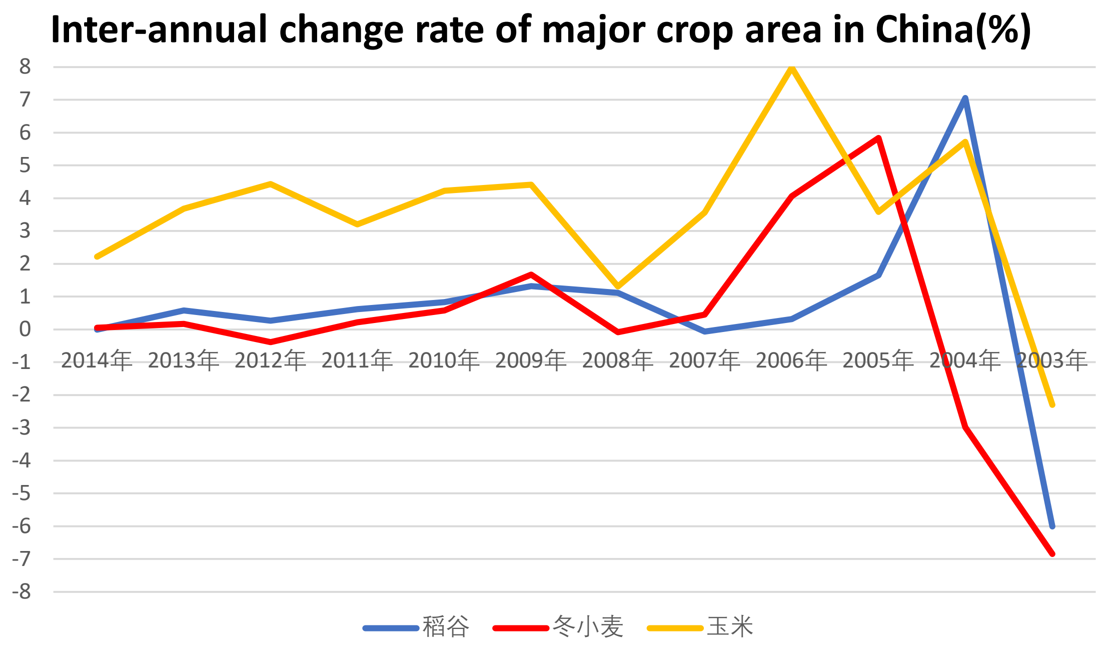
——To serve for disaster impact assessment and crop growth monitoring

——Lower accuracy

✓**Crop planting area**

——To serve for Total crop yield forecast

——To require high accuracy




● The inter annual change rate of major crop area is small;

● It is applicable in yield estimation only that the error of remote sensing crop area is lower than 5%

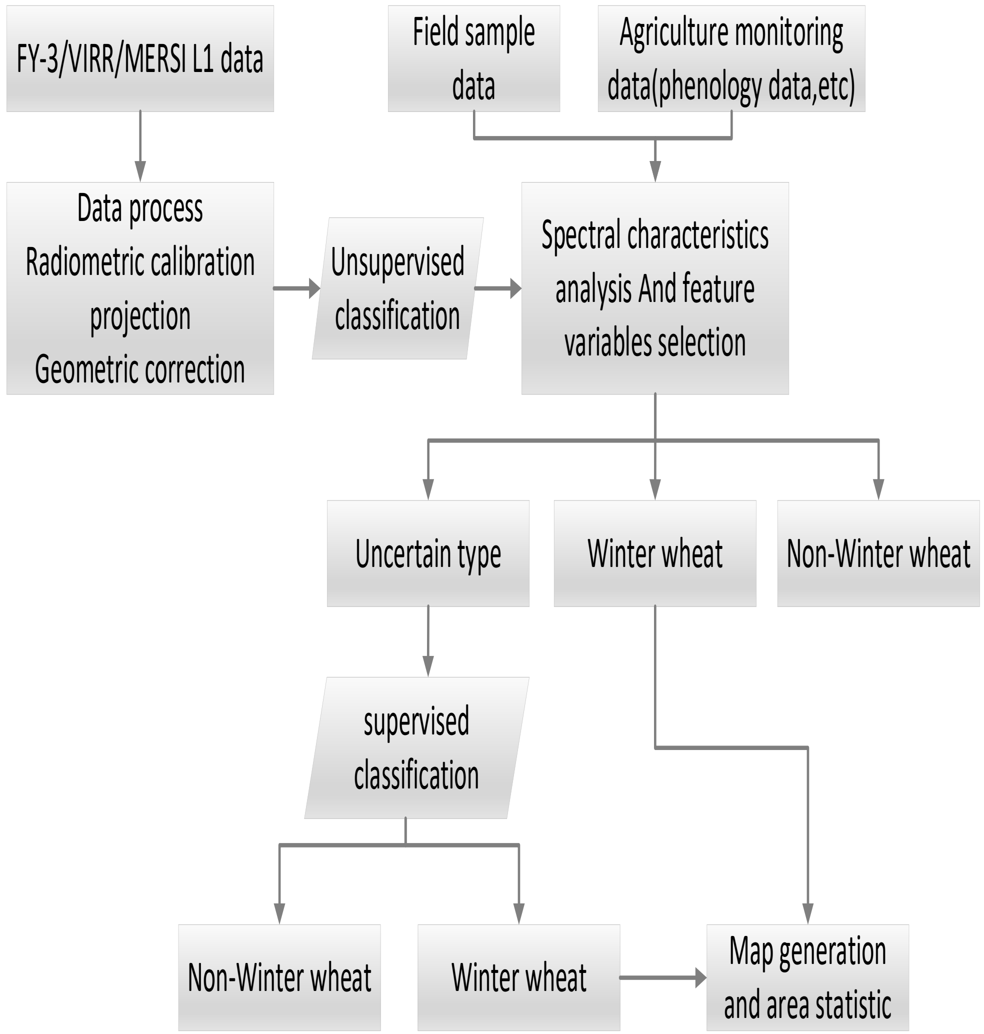
# Staple Crop Area Extraction-----methods

## extracting the planting area of certain crops in the whole region

- Combing with crop growth period, select remote sensing data of the appropriate period;
- remote sensing data cover the whole monitoring region and get full coverage information using low spatial resolution satellite data
- Large amount of satellite data
- Even if high spatial resolution data is used , the accuracy of planting area is difficult to beyond 95%.

## Stratified sampling to monitor the change rate of crop area in the sample area

- stratified sampling, establish and monitor the sample area;
- Combined with crop growth period, select remote sensing data of the appropriate time;
- extrapolate spatially change rate of area  to get the change rate of the whole region , calculate the crop area of whole region combined with the data of the previous year,
- disadvantage：  Unable to cover all monitoring area
- advantage：  high efficiency
- the accuracy can be guaranteed to be more than 95%.




- **Gather field samples and establish database**
- **Select and process temporal FY-3 data based on crop phenology**

Depend on Phenology data to determine the period of remote data;

combined phenology data with the historical crop data to predict the mixed crops, estimate the separable information of the mixed crops;

Construct the original expectation value of the crop time spectral pattern based on Phenology data.

Winter wheat (over-wintering period oct. –Dec., Turning Green Stage Feb.-Apr.)

- **Analyze spectral Characteristic of bands and construct feature variable of FY-3 data**

Those channels with more information, less correlation, large spectral difference and good. Further more, construct feature variables by using characteristic bands

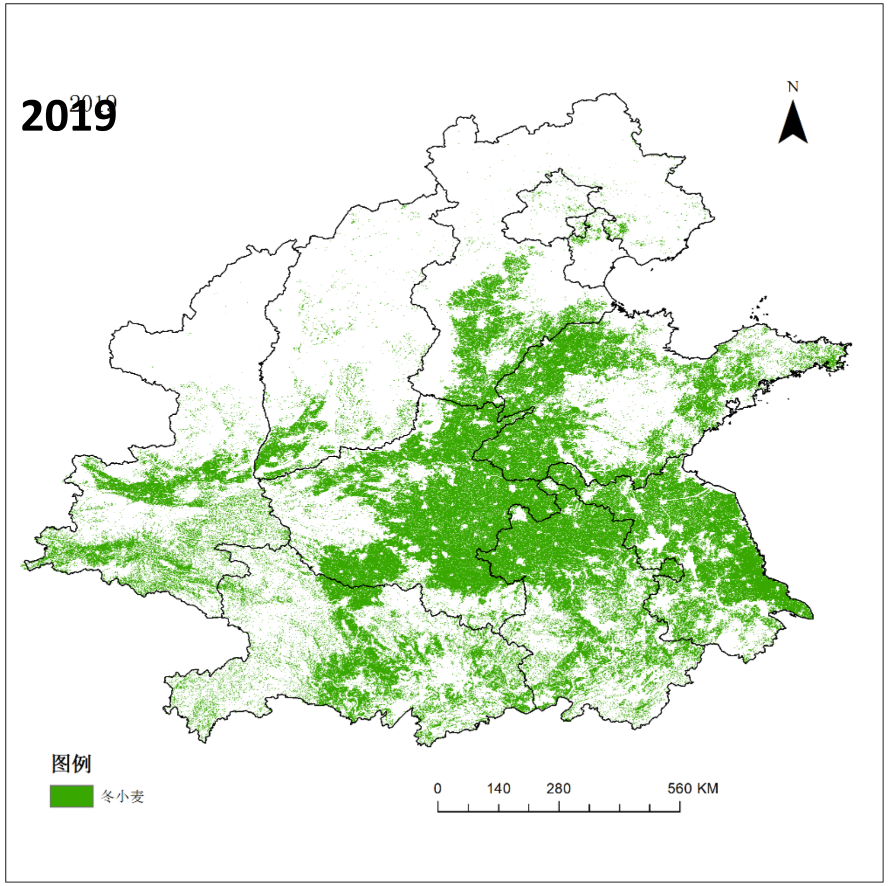
- **Extract crop area based on FY-3 data**

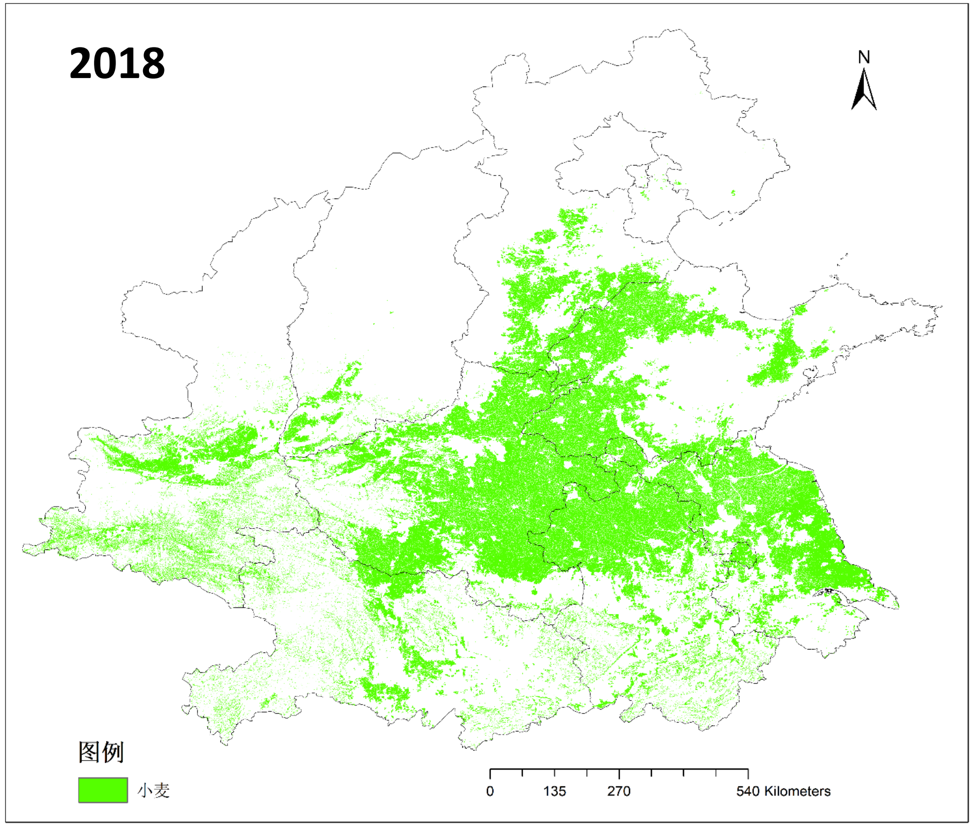
By analyzing the characteristics of crop TIME-SPECTRUM schema, image texture and time series, construct decision tree model. using supervised classification method for crops area extraction.

- **Validation and Map generation**

# winter wheat in major producing area of North China in 2018,2019

Using FY-3 data, we can extract  several kinds of staple crops area (winter wheat, corn, rice, etc.) dynamicaly, which can provide the basis for crop growth monitoring.




Compared with the areas of last year, The winter wheat areas of Henan, Shandong and Hebei in 2109 are same as those in 2018. the area of Anhui and Hubei increase this year  increase.

# Area extraction of Other crops in Jiangsu Province

rape

winter wheat

rice

corn

# Application 2----- Phenology Monitoring

remote sensing of crop phenology is to find out the significant changes in crop morphology, the corresponding date and the time of plant growth cycle.

The key of Phenology remote sensing is to define the detection **criteria** of phenology using the characteristics of VI time series curve and how to extract these information from time series data.

Three key growth periods is to be determined for Winter wheat phenology monitoring :

Turning green period -NDVI rise rapidly

Heading period - NDVI maximum, transformation from vegetative growth period to reproductive growth period),

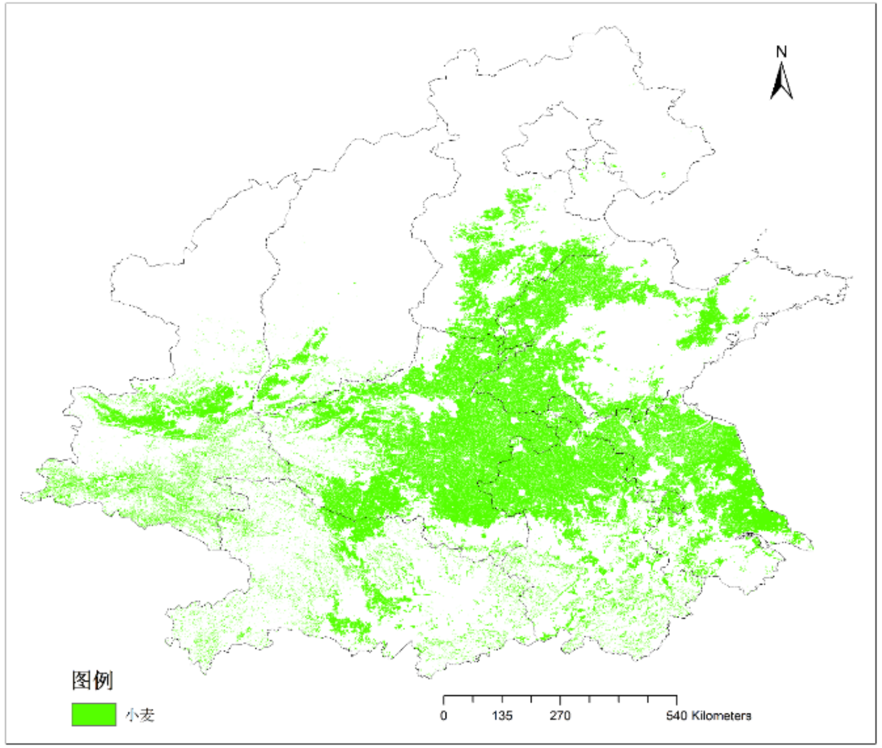
Maturation period-NDVI decline rapidly

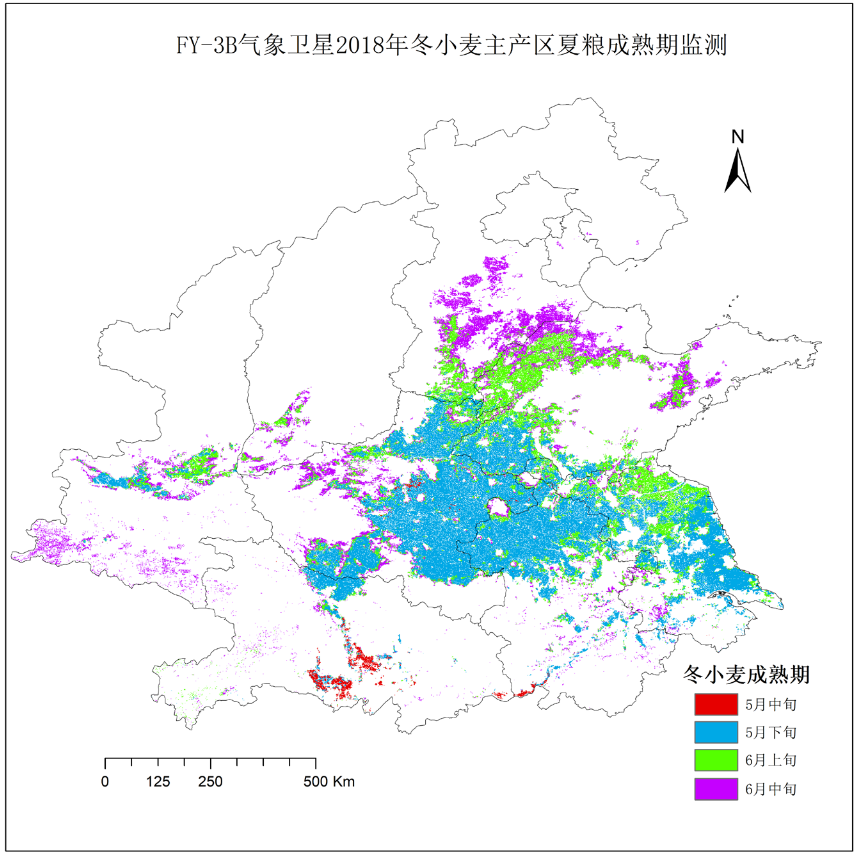
# Phenology Monitoring of Winter Wheat in Major Producing Area

## processing flow

- Establish ten-day NDVI series of FY-3(VIRR/MERSI) based on winter wheat growth phenology ,
- Time series smoothing process : Adopt time series smoothing method(e.g S-G filter) to eliminate the influence of cloud and noise) in order that the trend of VI time series coincide with the real vegetation growth rhythm .
- Construct crop growth curve in the pixel scale
- Make linear regression on the VI data in the sliding time window, using the maximum slope method to determine turning green period , heading period, harvest period.

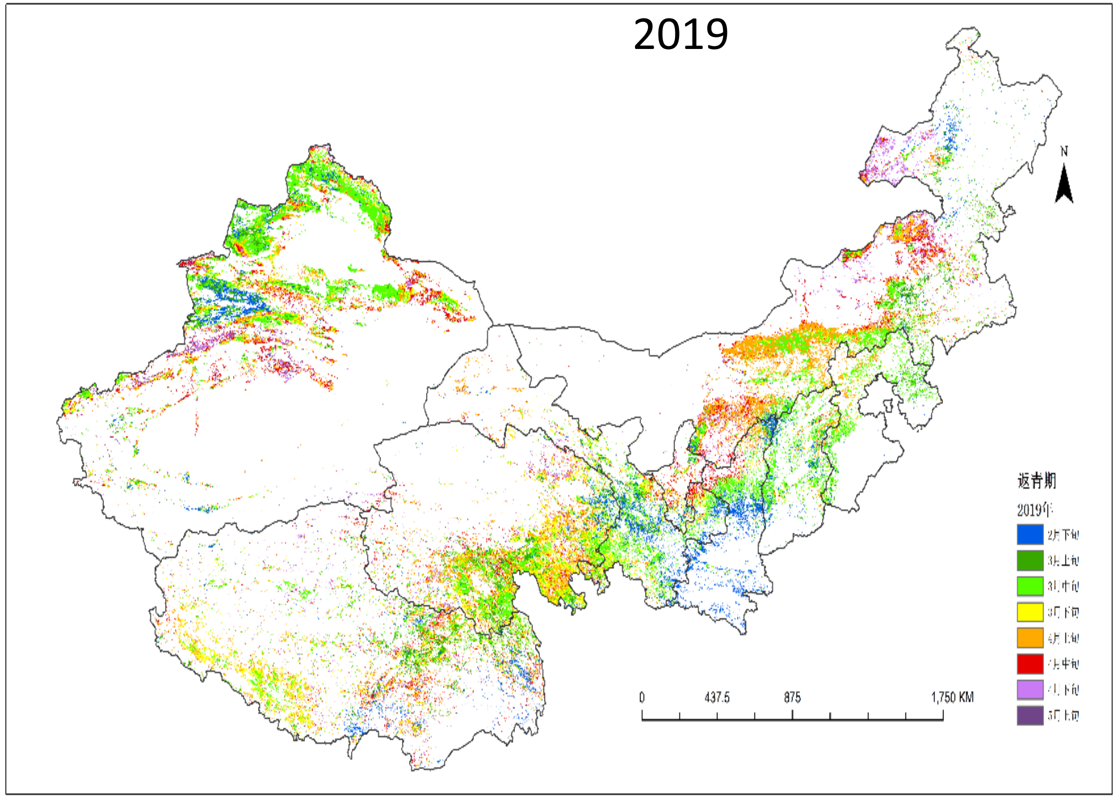
# Maturation Period of Major Producing Area of Winter Wheat in 2018

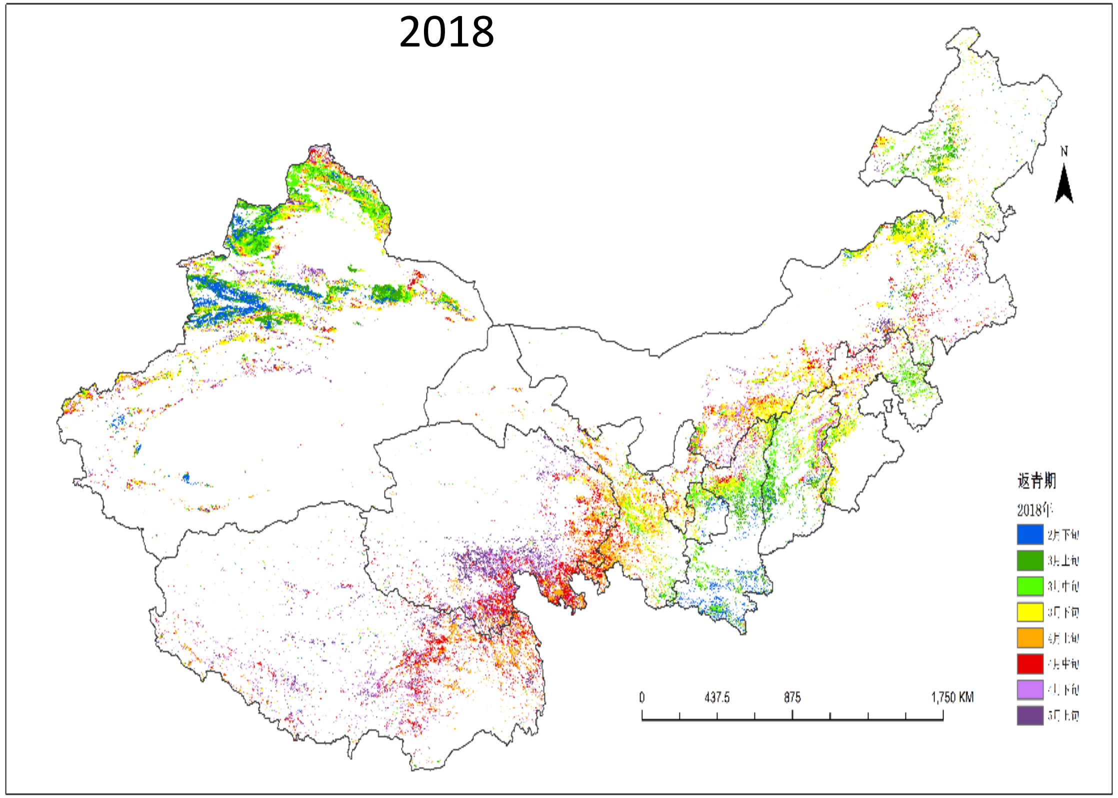



In the last ten days of May, 2018， winter wheat in the northwest of Hubei, the middle and east of Henan, the southwest of Shandong , the north of Anhui and the middle of Jiangsu entered into maturation period.

# Regreening Period of Grassland in China




Compared with the period of 2018, the regreening period of this yearn in Tibet Plateau is generally advanced by about 20 days ; period in central Inner Mongolia is delayed by about 10 days; and that of other regions is much the same.

Using FY-3B/VIRR NDVI from the first ten days of Jan. till the middle ten days of May in 2108 and 2019.

# Application 3----- Crop growth monitoring

**Crop growth monitoring of remote sensing**

refers to the macro monitoring of crop seedling, growth and its changes, providing the basis for crop yield estimation in early stage

**real-time growth monitoring**

Find crop growth change by comparing the real-time VI with last year’s or multi-year average, as well as a specified year. The differences can be classified and statistically displayed.

**growth trend analysis**

To be constructed by the time series VI data, and the crop growth state is reflected by the inter annual comparison of the growth process curve.

# growth monitoring --- real-time growth monitoring

- Difference Index （DI）

$$DI_j = NDVI_j - NDVI_{ref}$$

Where, $NDVI_j$ , $NDVI_{ref}$ are NDVI of current j and NDVI of reference year. The bigger DI, the better crop growth.

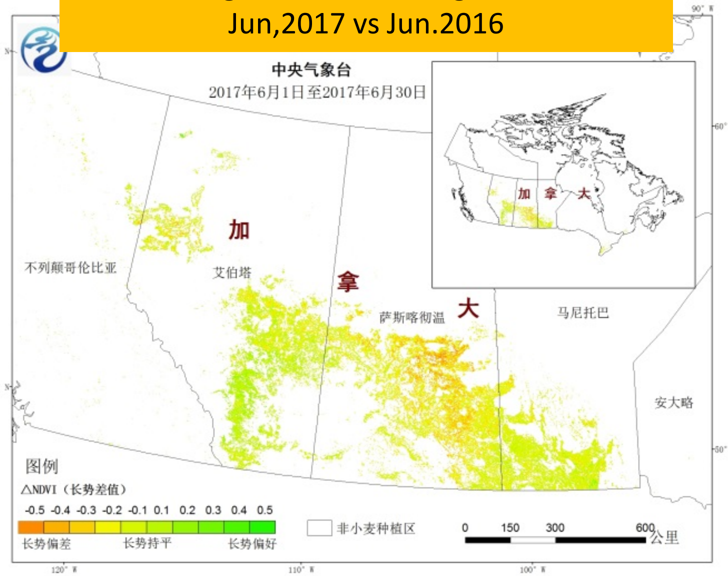
- Vegetation Condition Index （VCI）

$$\mathrm{VCI}_j = \frac{NDVI_j - NDVI_{min}}{NDVI_{max} - NDVI_{min}}$$

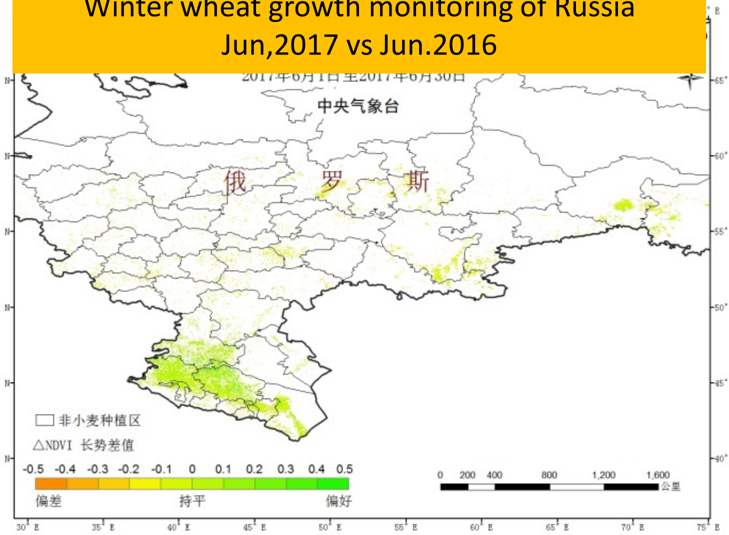
Where， $\mathrm{VCI}_j$ —— VCI of period(time) j， $NDVI_j$ is NDVI of period(time) j， $NDVI_{max}$ is the max NDVI of the same period(time) over many years，， $NDVI_{\mathrm{min}}$ is NDVI of the same period(time) over many years. The bigger VCI, the better crop growth.

# Crop growth monitoring in global major producing area —Real time monitoring

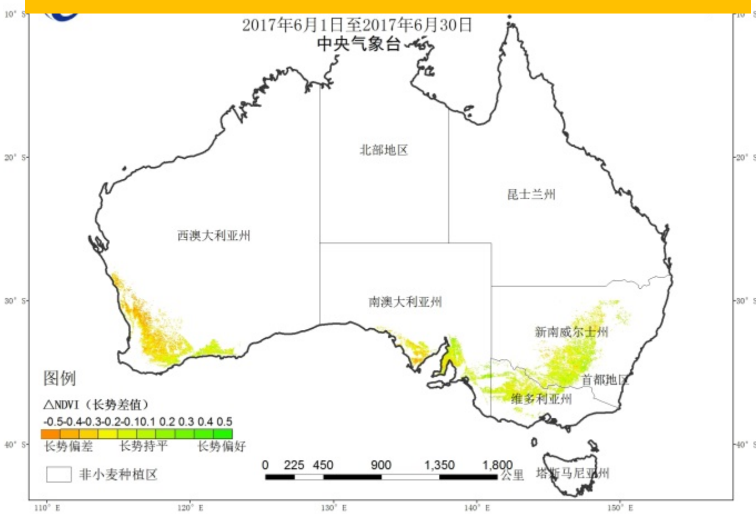
Wheat growth monitoring of Canada
Jun,2017 vs Jun.2016



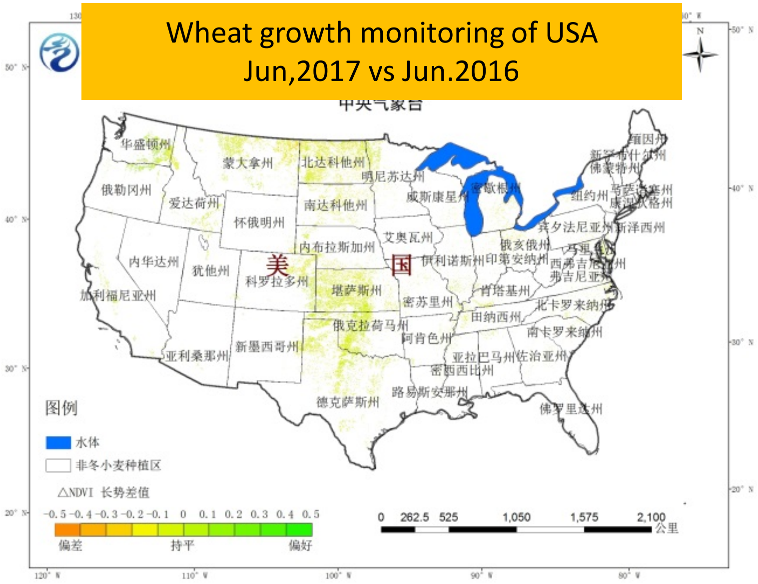

Winter wheat growth monitoring of Russia
Jun,2017 vs Jun.2016



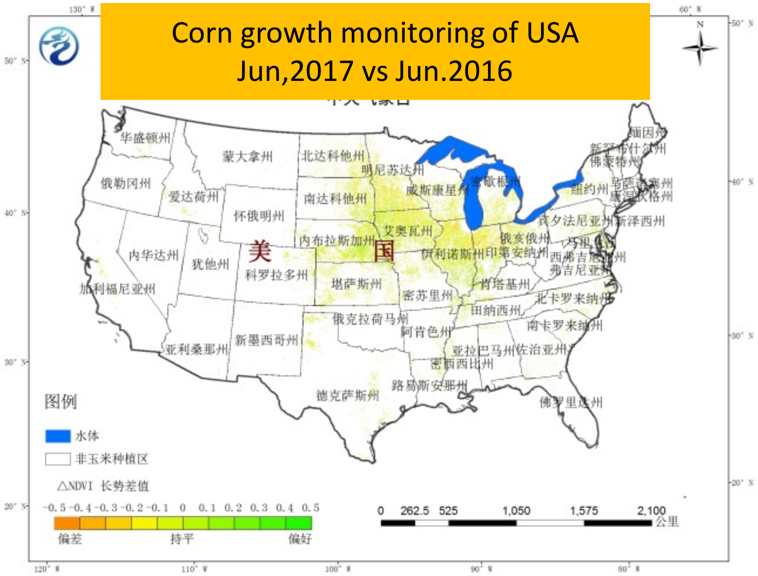

wheat growth monitoring of Australia
Jun,2017 vs Jun.2016



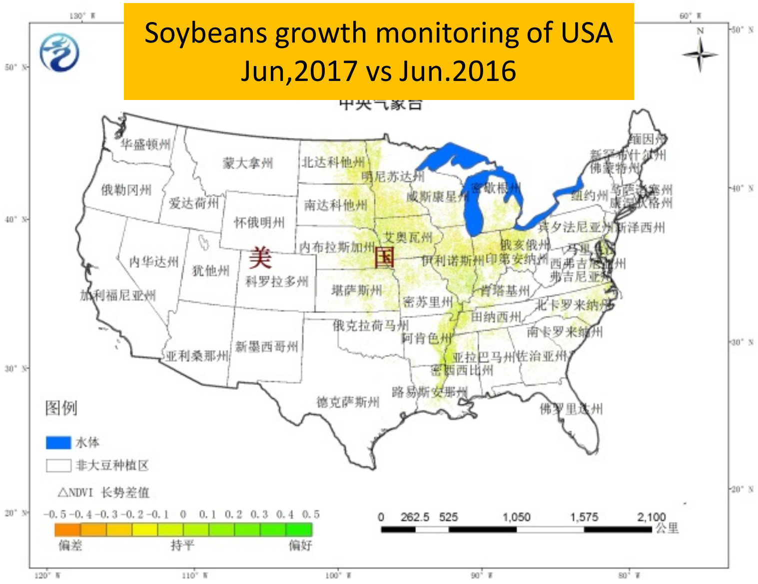

Wheat growth monitoring of USA
Jun,2017 vs Jun.2016




Corn growth monitoring of USA
Jun,2017 vs Jun.2016

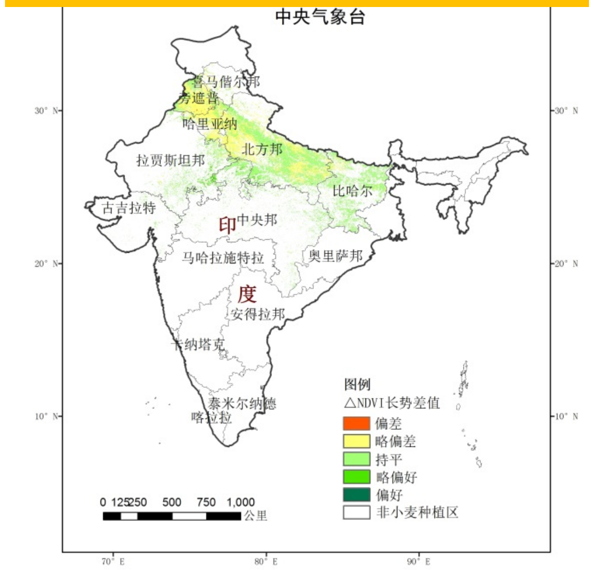



Soybeans growth monitoring of USA
Jun,2017 vs Jun.2016

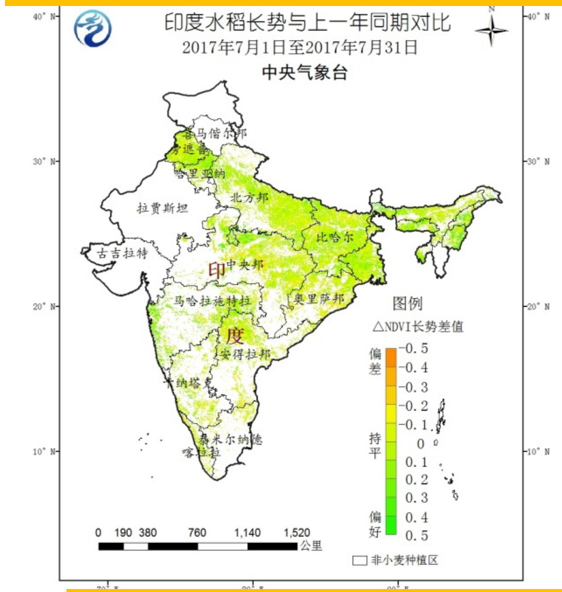


# Crop growth monitoring in global major producing area —Real time monitoring

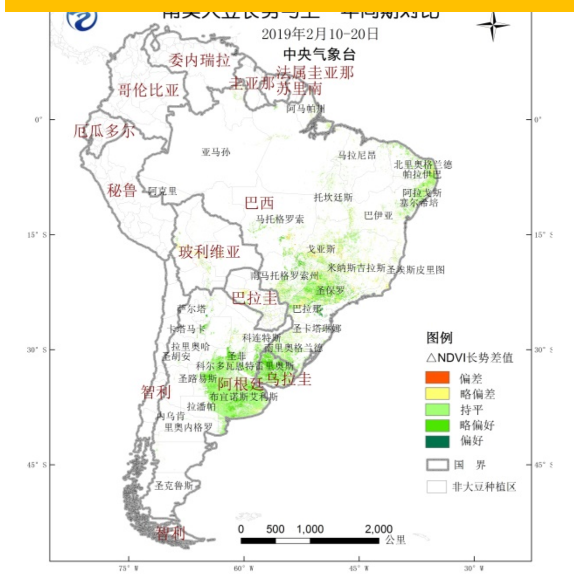
Wheat growth monitoring of India
Feb.10-20 2019 vs Feb,10-20, 2018



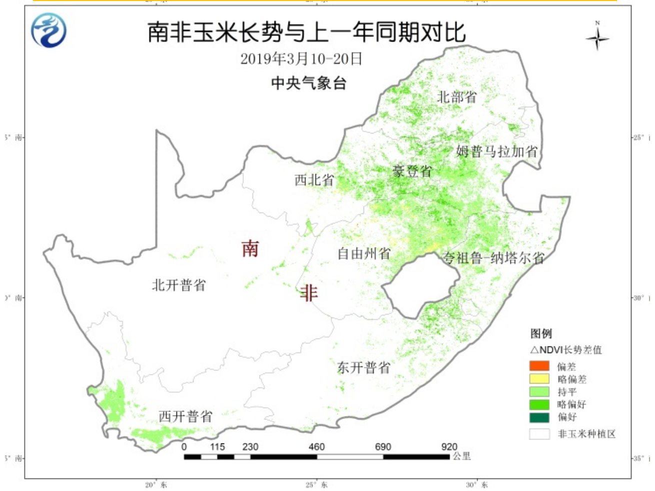

Rice growth monitoring of Russia
Jul.2017 vs Jul.2016



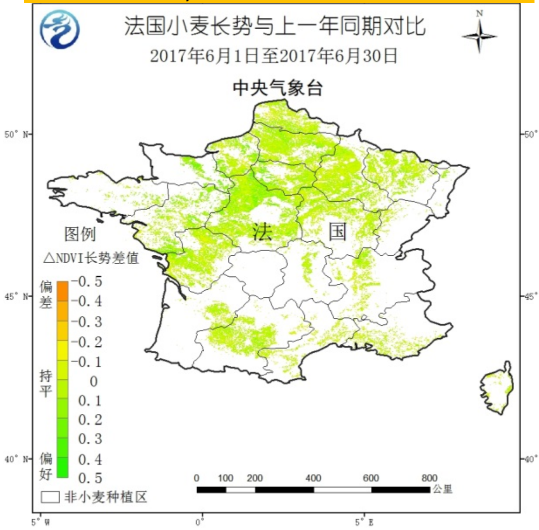

Soybeans growth monitoring of South America
Feb.10-20 2019 vs Feb.10-20, 2018



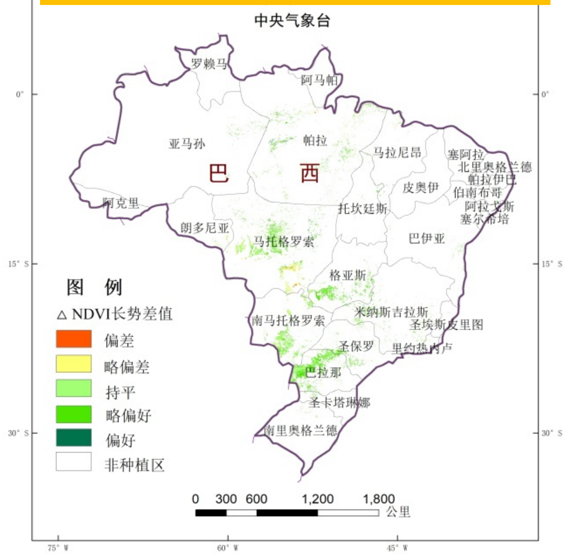

corn growth monitoring of South Africa
Mar.0-20 2019 vs Mar.10-20, 2018



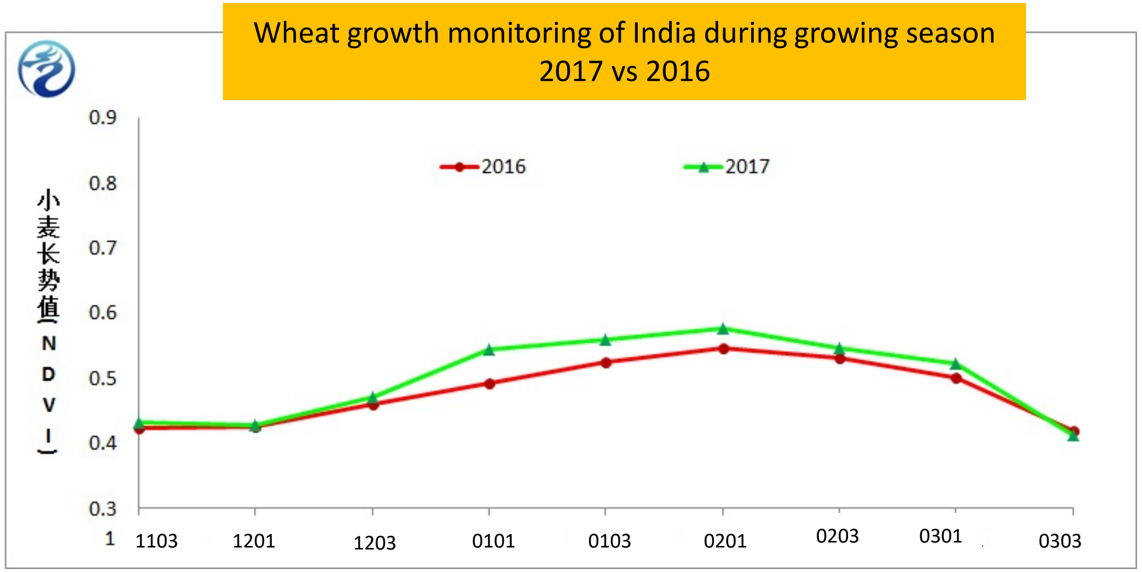

Wheat growth monitoring of France
Jun,2017 vs Jun.2016

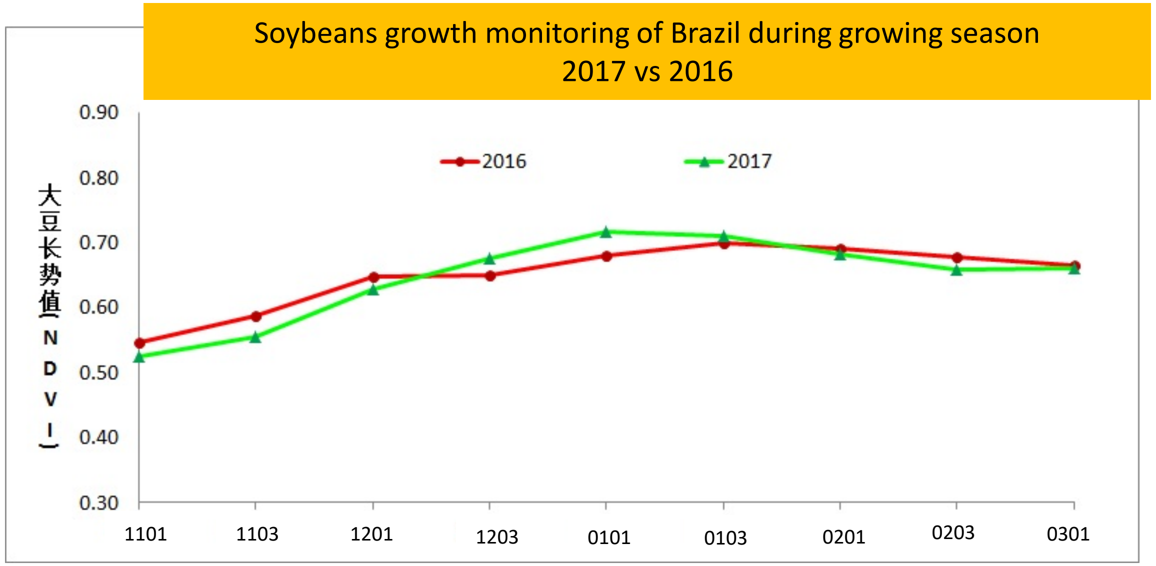


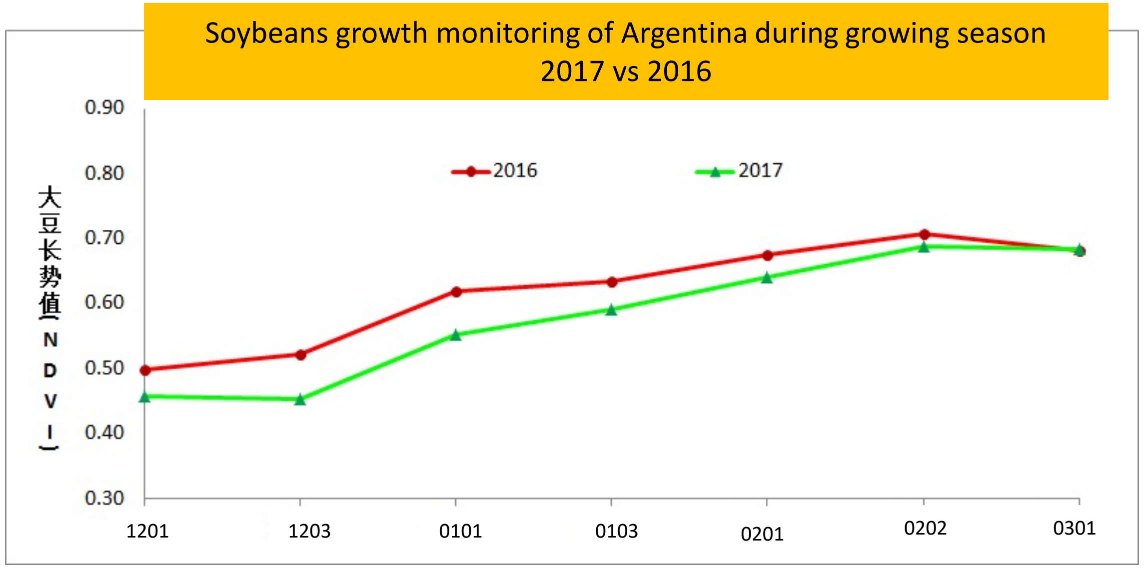

corn growth monitoring of Brazil
Jun,2017 vs Jun.2016

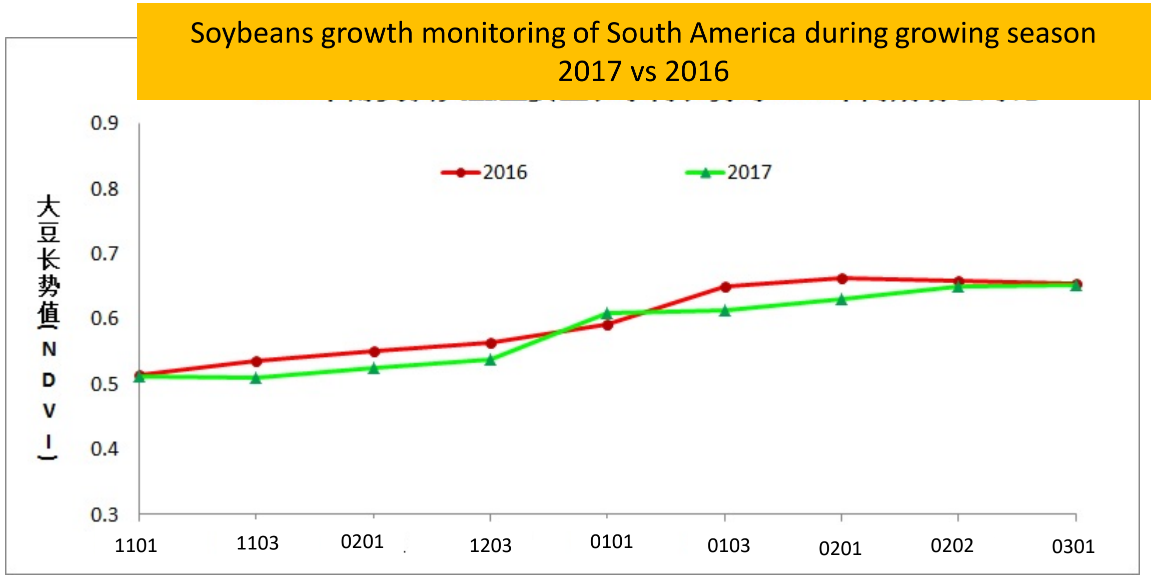


# Crop growth monitoring in global major producing area—Growth trend analysis



Foreign Agrometeorological monitoring and crop yield prospect

# 国外农业气象监测与作物产量展望

2019 年 第 4 期 VOL. 14 NO. 4

中国气象局中央气象台 制作：何 亮
签发：郭安红 2019 年 5 月 5 日

## 印度小麦总产将创历史新高
## 美国欧洲大部小麦长势良好

**概要：** 4 月，美国和欧洲大部冬麦区水热匹配总体较好，利于小麦生长发育，小麦长势良好；巴西大豆和头季玉米产区多晴好天气收获已基本结束；印度小麦产区大部光温水适宜，气象条件总体较好。气象卫星遥感动态监测显示 2 月下旬以来印度小麦长势好于上年和近 5 年，预计 2019 年印度小麦平均单产比 2018 年增加 4.5%；总产量比 2018 年增加 1.9%，将创历史新高。5 月，需关注水热条件对美国和欧洲冬小麦、巴西二季玉米等产量形成的影响以及美国玉米、大豆等春播作物播种出苗的影响。

### 一、农业气象监测

4 月，北半球美国冬小麦处于拔节至孕穗抽穗阶段，欧洲大部冬小麦处于返青起身拔节期，南部意大利等地处于孕穗期；印度小麦处于成熟收获期；南半球巴西大豆和头季玉米、阿根廷大豆和玉米、南非玉米处于成熟收获阶段；巴西二季玉米处于拔节至抽雄开花期。

#### 1、北美

4 月，美国冬麦区大部气温接近常年同期或偏高 1～2℃（图 1 左），其中中南部冬麦区月平均气温普遍为 8～12℃，部分地区为 16～20℃，北部冬麦区在 4℃～8℃。主产区大部降水量有 10～



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India‘s total wheat production will reach a new highest record, and the wheat growth of the most of USA and Europe will grow well.

**印度小麦总产将创历史新高。** 2018-2019 年度印度小麦生长季热量充足；水分条件总体良好，虽然部分地区因播种期降水不足导致播种偏晚，但后期降水充足，小麦苗情陆续转化升级并形成丰产群体；整个生长季无大范围干旱和洪涝灾害，水热匹配利于小麦生长发育和产量形成。卫星遥感动态监测显示，2 月下旬以来，印度小麦主产区平均归一化植被指数[1]（DNVI）均高于去年同期和近五年平均，长势好于上年和近五年（图 6）。


**图 6 2018 年 11 月以来印度小麦主产区 NDVI 逐旬动态监测**

预计 2019 年印度小麦平均单产为 3297 公斤/公顷（图 7），比 2018 年（3154 公斤/公顷）增加 4.5%，比近五年平均增加 7.7%；2019 年小麦种植面积为 30000 千公顷，比 2018 年（30790 千公顷）减少 2.6%，比近五年平均减少 2.4%。预计 2019 年印度小麦总产量为 9891 万吨，比 2018 年（9711 万吨）增产 180 万吨，增幅 1.9%（见附表）；与近五年平均相比，总产增加 485 万吨，增幅 5.2%，为历史最高产年。

[1] NDVI，归一化植被指数，反应植被生长状况，值越大表示长势越好。



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Growth trend analysis shows :since last 10 days of Feb, NDVI of India's main wheat producing areas has been higher than the average of the same period of last year and the recent five years, which means the growth trend is better than the one of the last year and the recent five years.

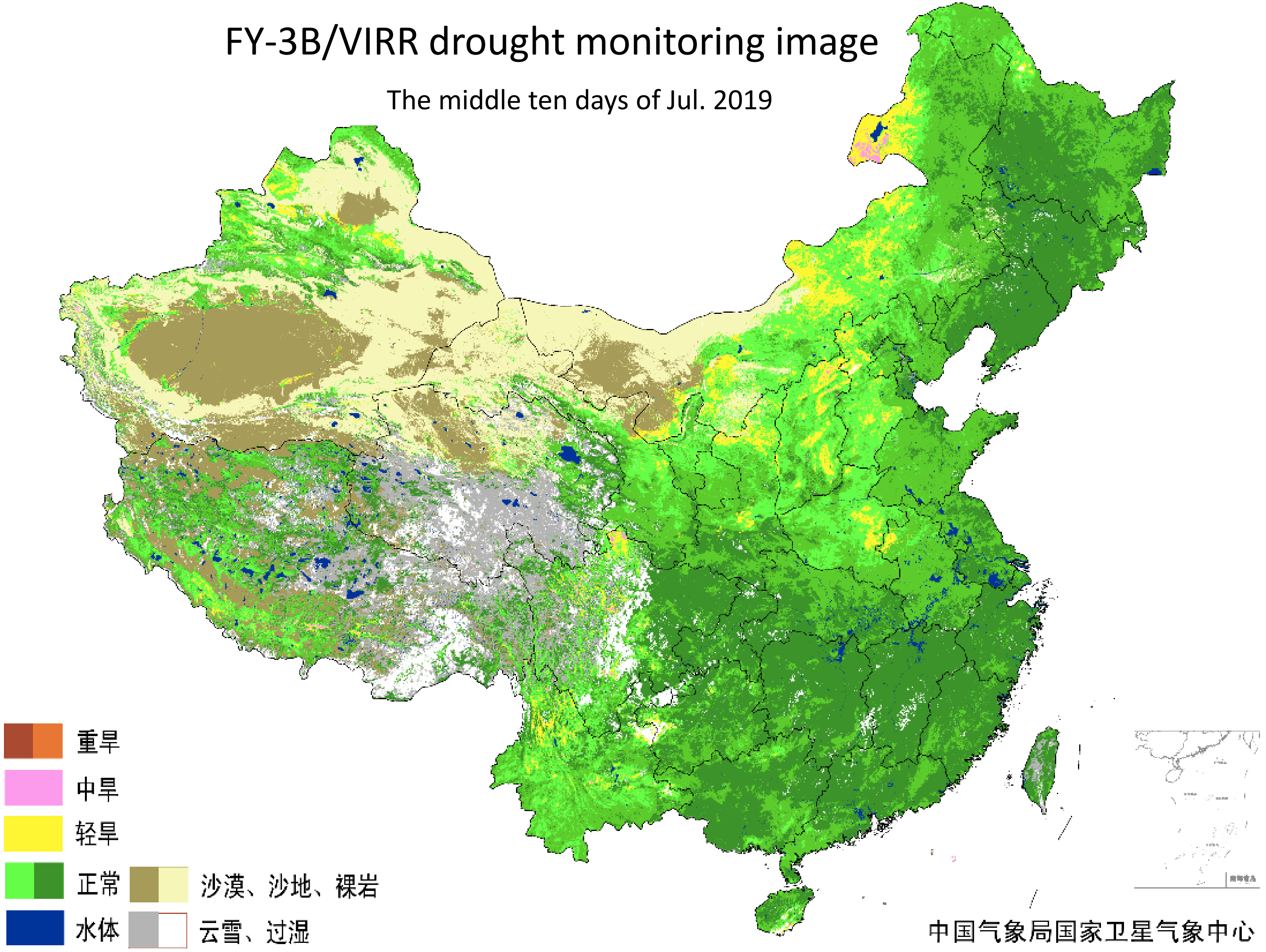
It is estimated that the average wheat yield per unit of India in 2019 will increase by 4.5% compared with that in 2018 and 7.7% compared with that in recent five years.

# Application 4----- Drought Monitoring

- Established remote sensing drought monitoring operation in 2002.
- Based on thermal  Inertia method, using FY-3B/VIRR data, generate nationwide drought image every ten days .
- Based on FY-2, generate nationwide RET image and Anomaly percentage of RET every ten days and every month.
- Depending on the ability of FY-3 global observation,  apply FY-3 soil moisture, NDVI and RET to monitor the global drought events.

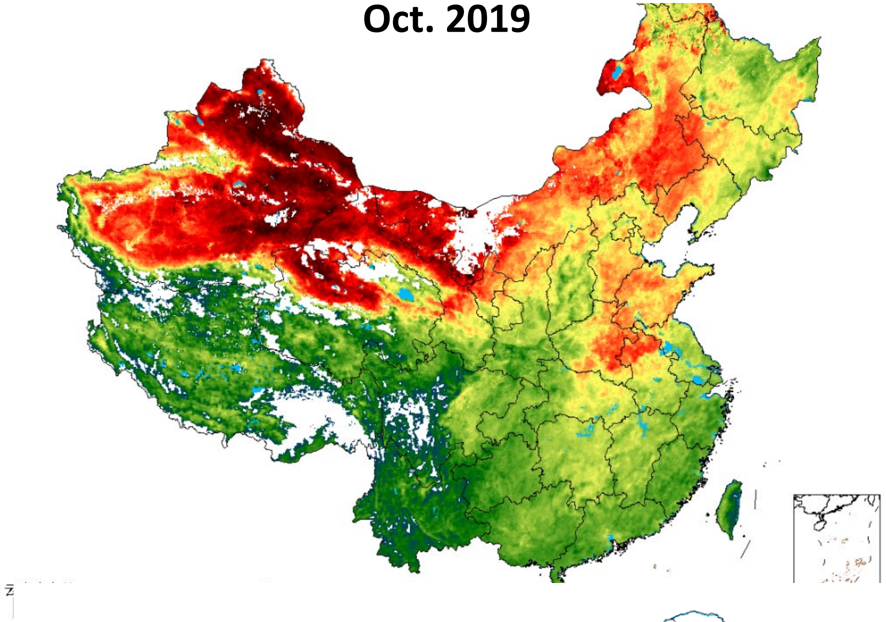
# FY-3B/VIRR drought monitoring image

The middle ten days of Jul. 2019

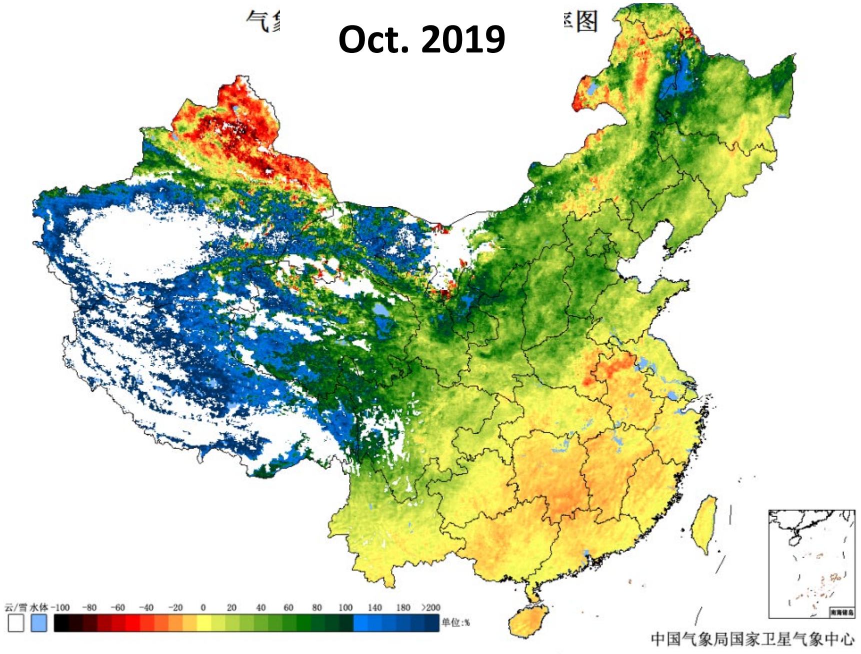


# FY-2 Anomaly Percentage of RET

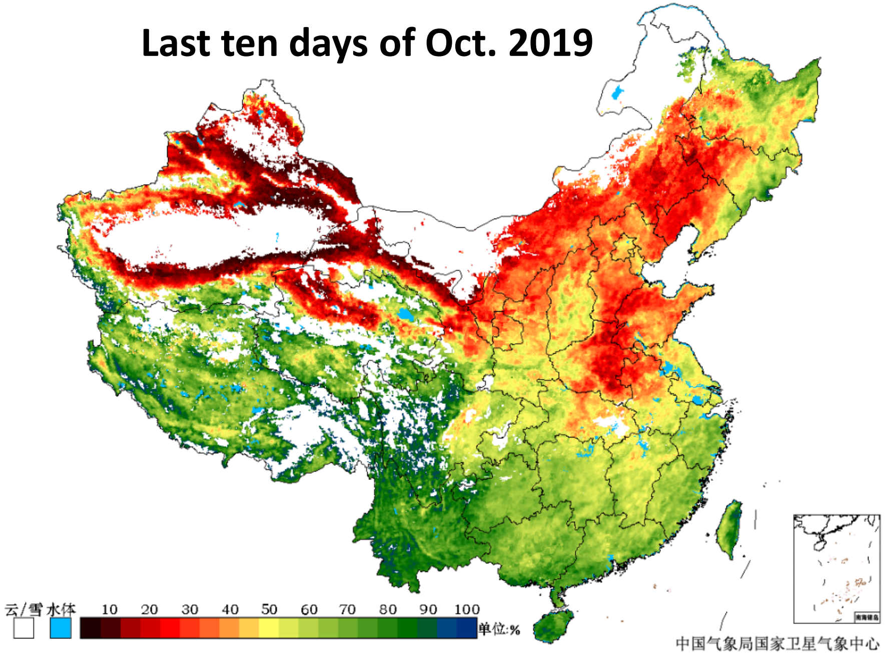
FY-2 RET
Oct. 2019



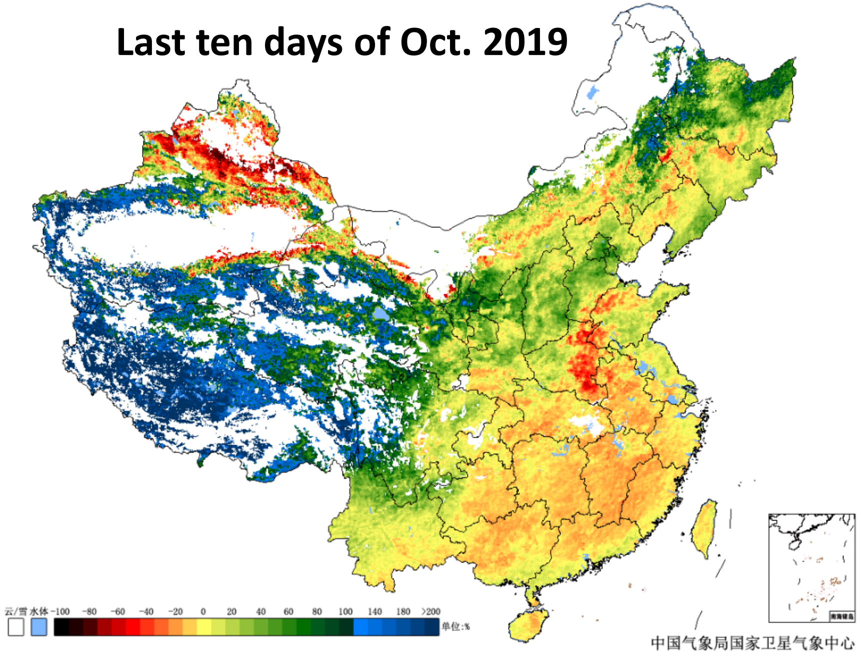
Oct. 2019




Last ten days of Oct. 2019




Last ten days of Oct. 2019



# Drought Monitoring

**FY product**

- FY-3 VSM
- FY-3 NDVI
- FY-2/4 RET

**Construct temporal dataset**

- FY-3B/MWRI SM （daily/ten days/monthly,2012-）
- FY-3B NDVI (ten days/monthly,2012-）
- FY-2 (RET ten days/monthly,2004-）

**Establish the drought index based on temporal data**

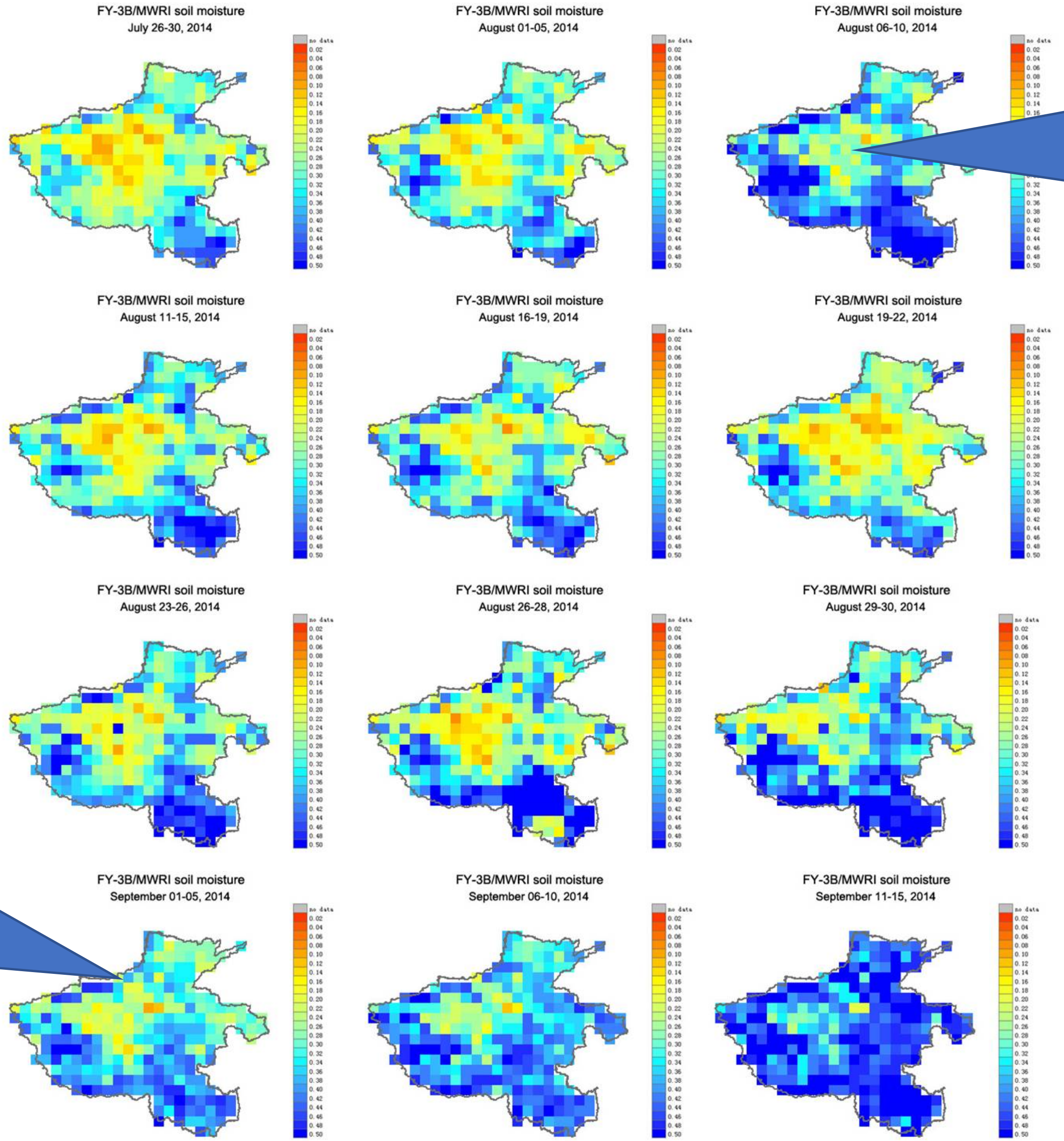
- anomaly（NDVI、VSM）
- Anomaly percentage（RET、VSM）
- Normalizing Index（SM）

**Apply in drought monitor**

- Civil drought events
- Global drought events

**Improvement of drought monitoring methods and indicators**

# Drought Monitoring of Henan province----FY-3B/MWRI Soil Moisture

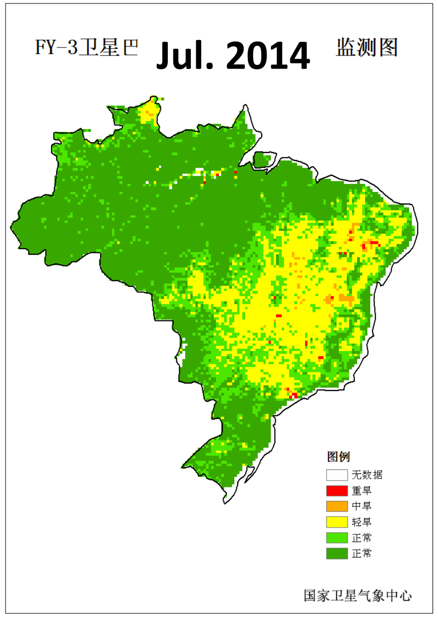


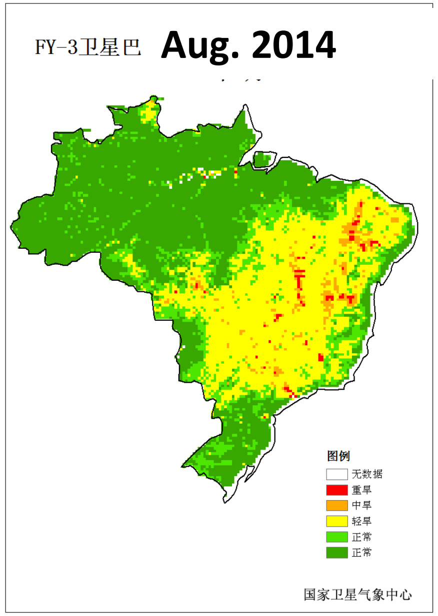

**There is a weak process of rainfall, and the soil moisture has increased, drought relieved temporarily**

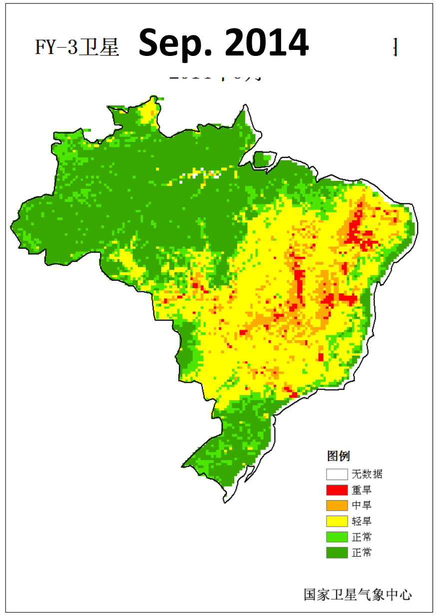
**Because of a continuous precipitation, soil moisture increased significantly and constantly.**

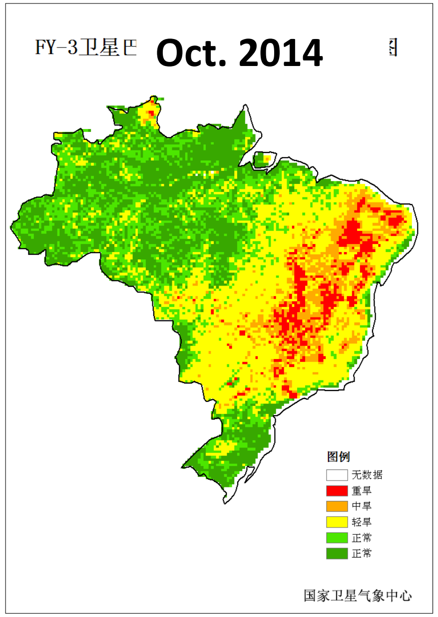
FY-3/MWRI SM is sensitive to rainfall. And Microwave can pass through the cloud, which is the obvious advantage compared with drought indices based on optical sensor.

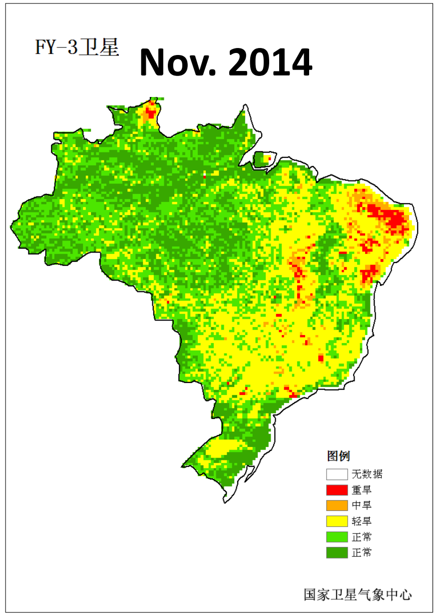
# Drought monitoring of Brazil----FY-3B/MWRI soil moisture

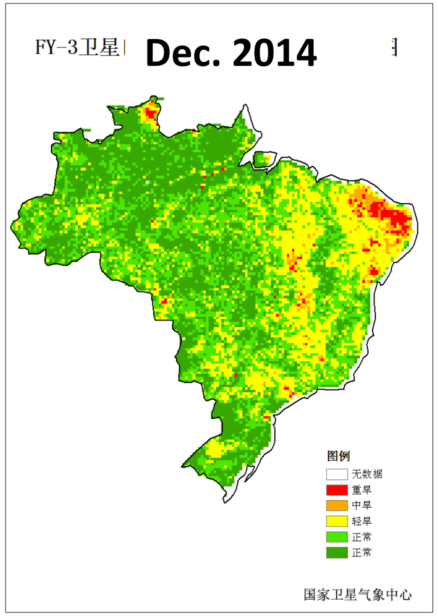


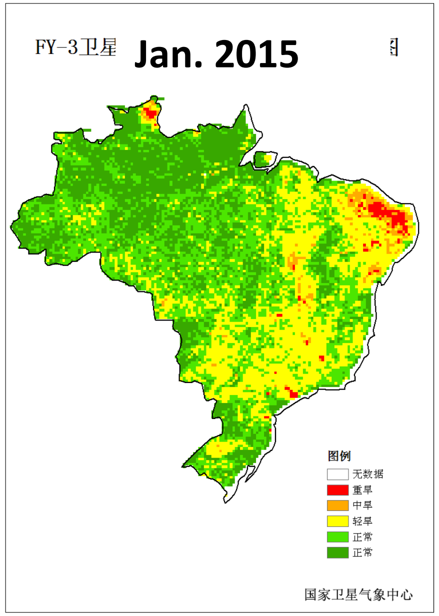



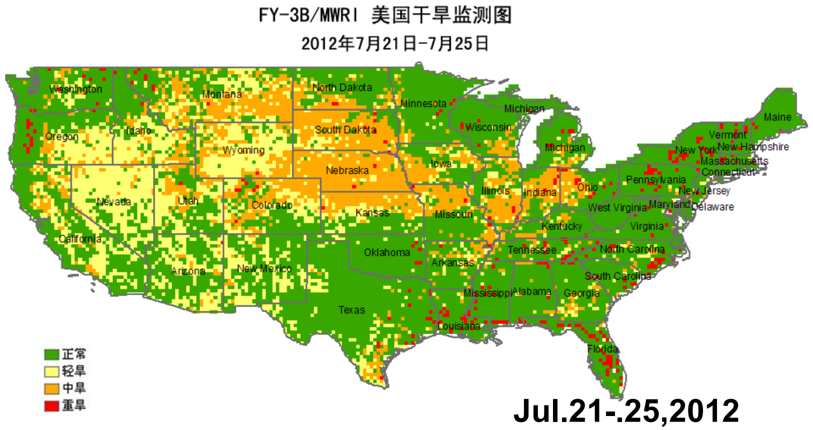



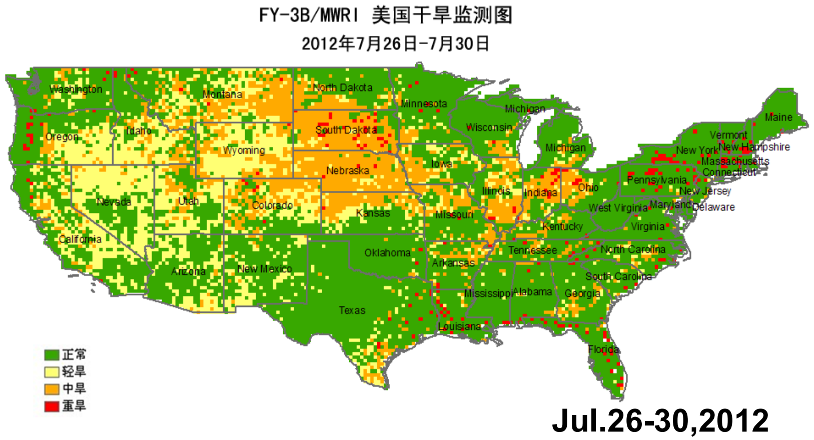



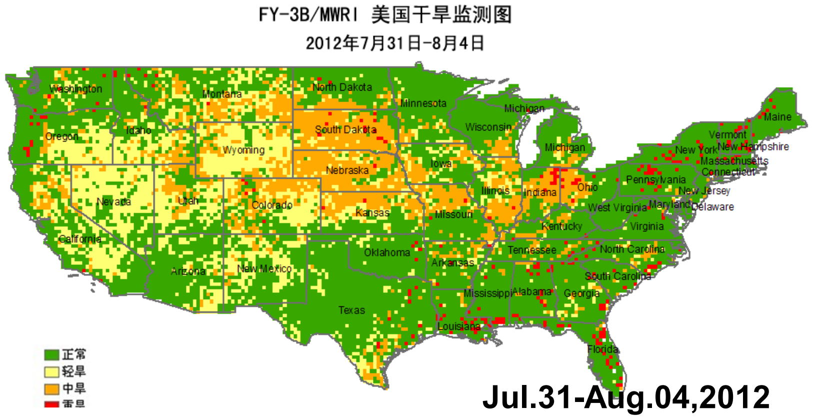



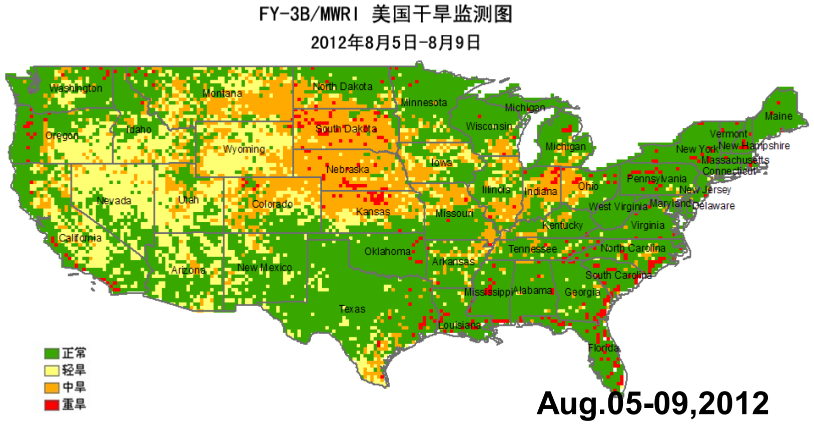

FY-3B SM , since July 2014, there has been a large-scale drought in the eastern and south central parts of Brazil. From Sep to Oct, the drought in the eastern region has intensified, and some regions have reached

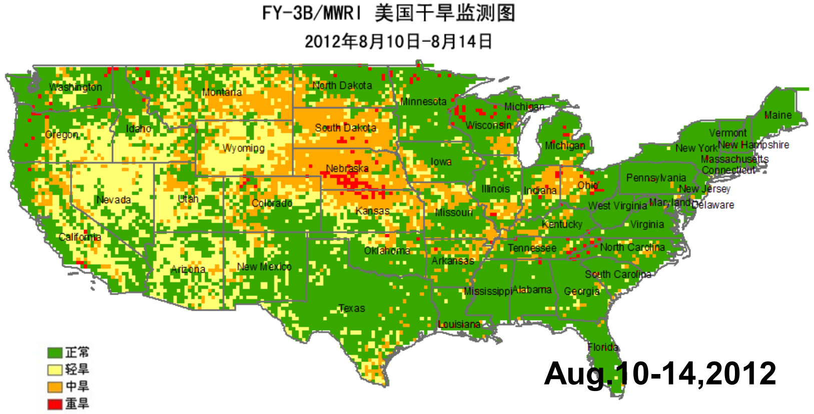
# Drought monitoring of USA----soil moisture difference

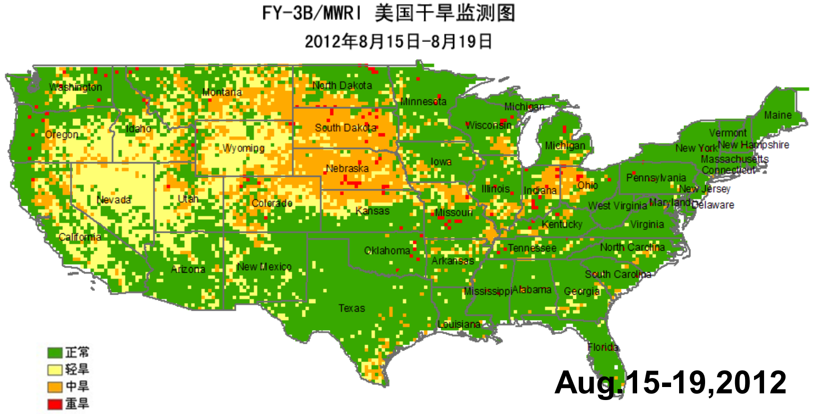


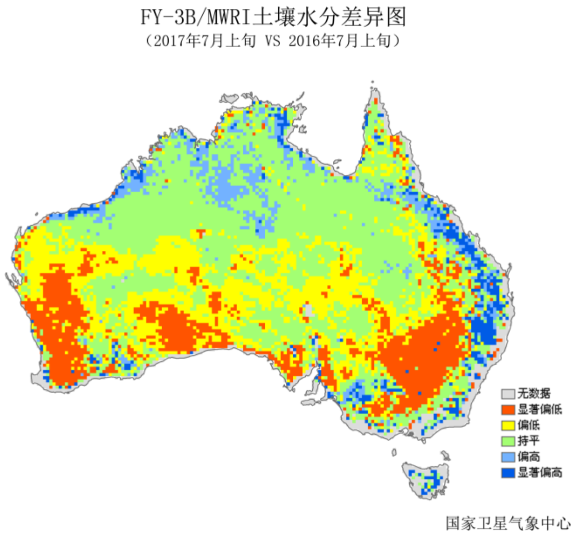



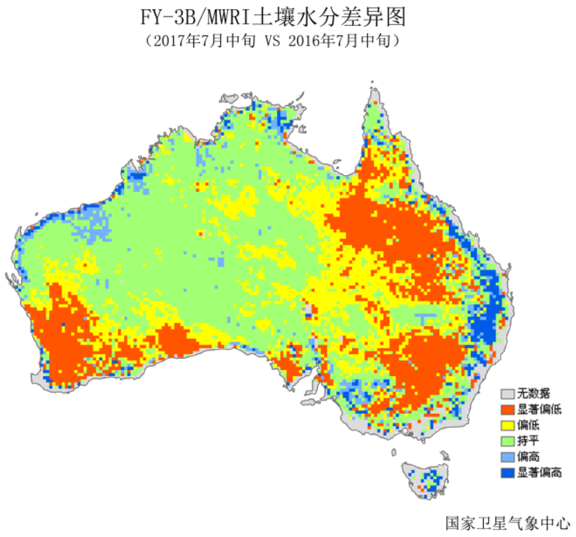



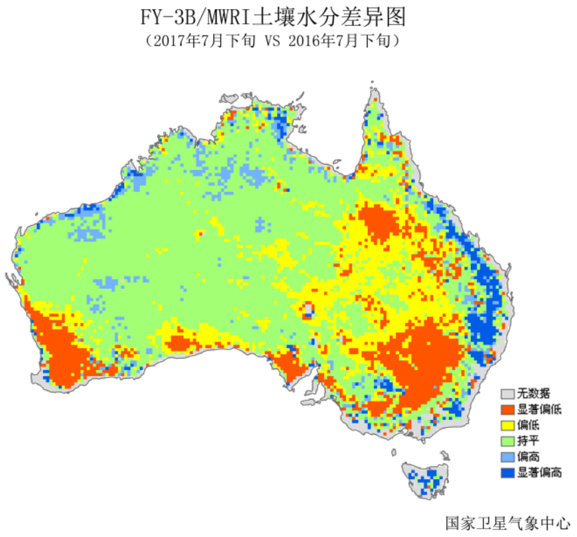



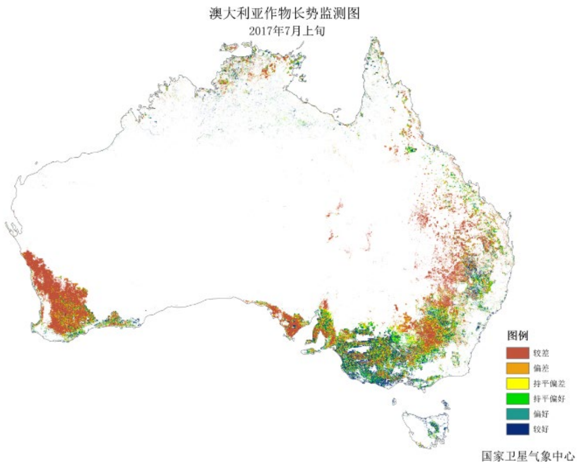



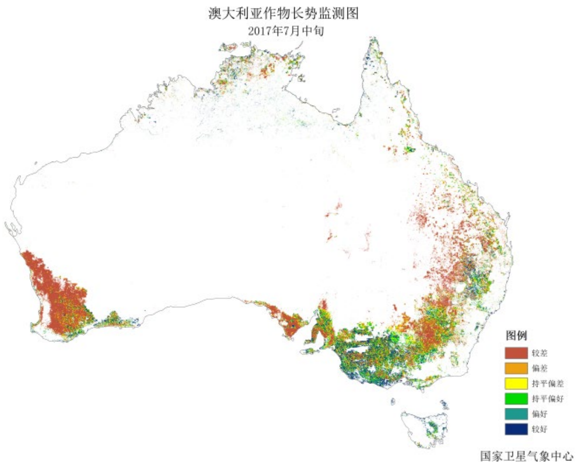
# Drought monitoring of Australia --- SM difference & NDVI anomaly

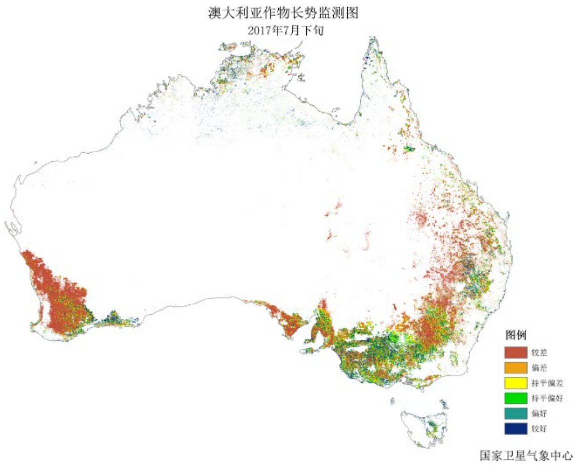


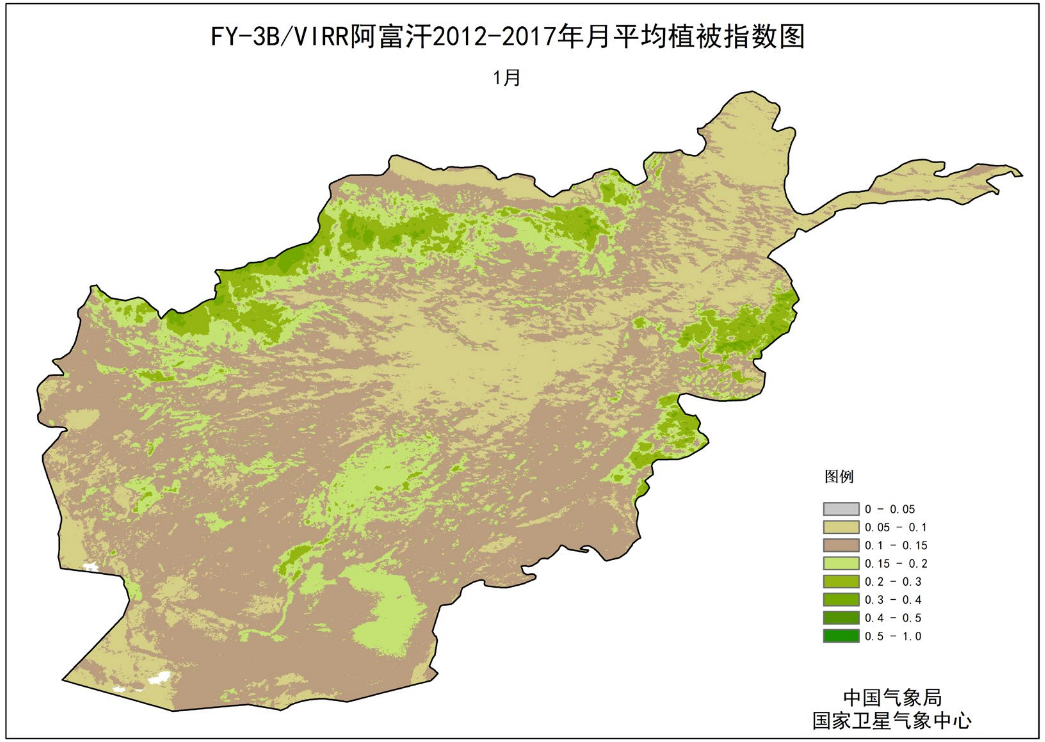



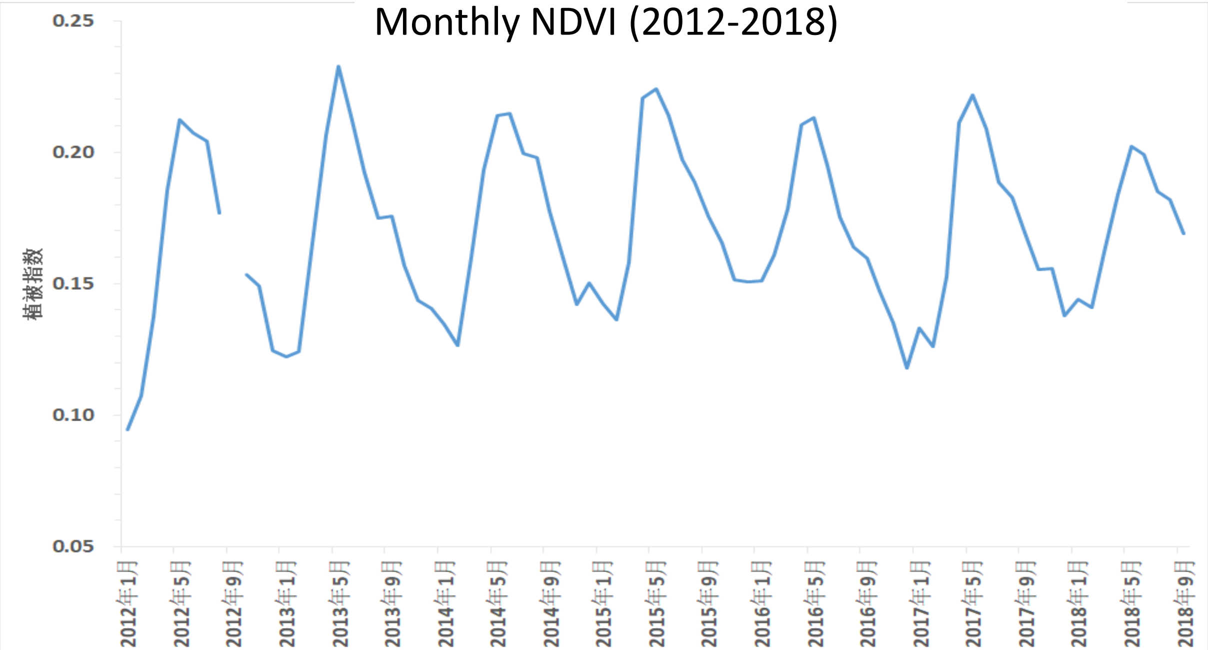



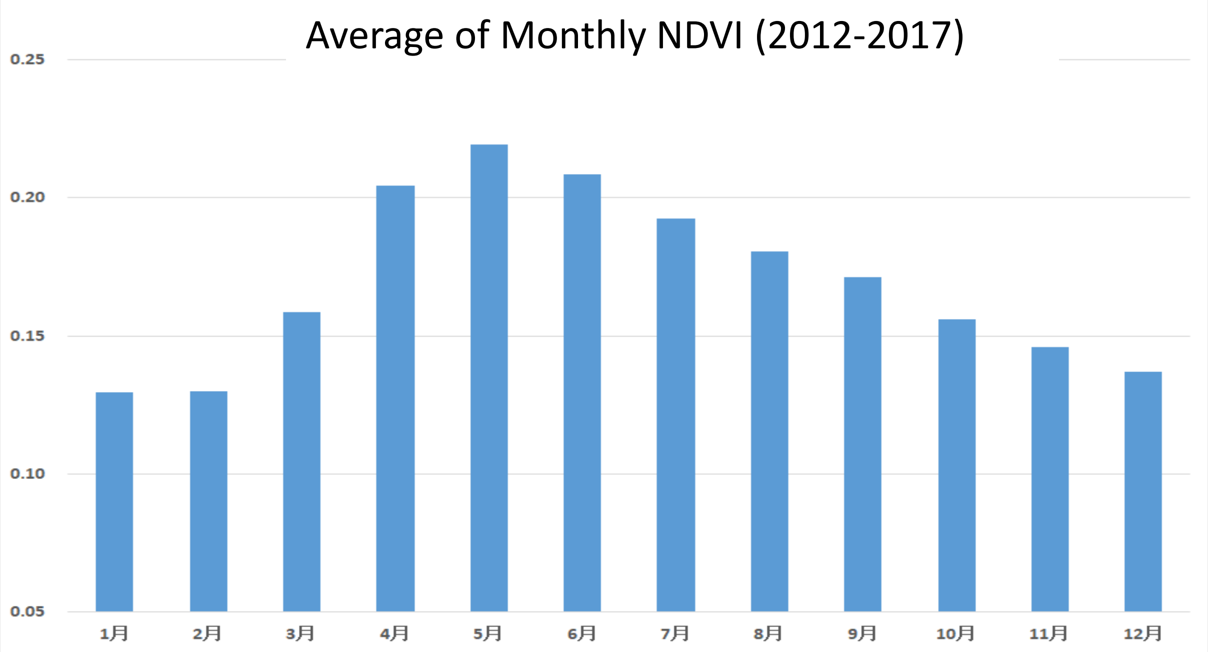

In the first ten days of July, the soil moisture in southwest, South and east parts of Australia was significantly lower than that during the same period of previous year, and the area of the lower soil moisture in the middle ten days of Jul was obviously increased. In the last ten days, the situation of the low soil moisture was improved. The crop growth in the lower  areas of soil moisture is worse than the average in the same period of the previous five years.

# Drought monitoring of Afghanistan -- SM anomaly & NDVI anomaly

Average of Monthly NDVI (2012-2017)

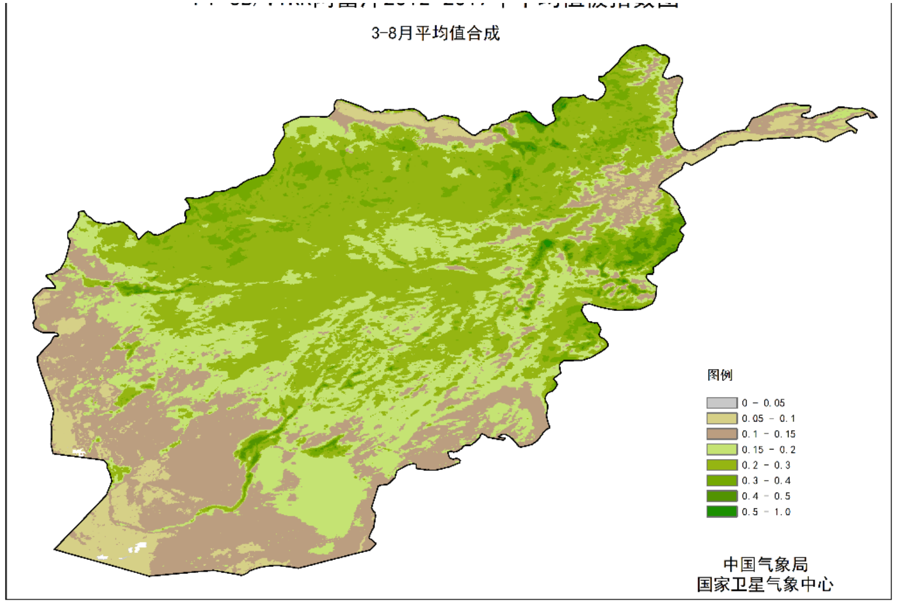


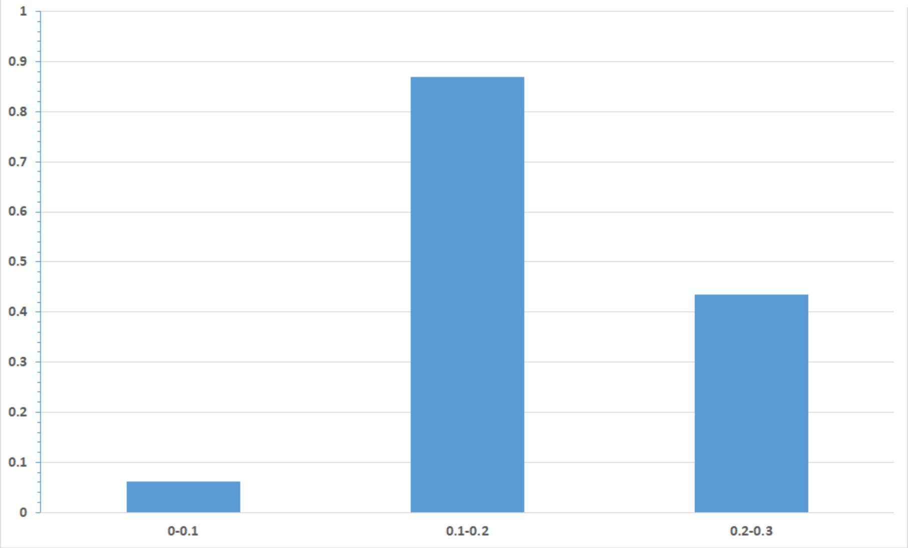




The maximum NDVI in Afghanistan appears in May, and the minimum NDVI appears in January February. The maximum NDVI in Afghanistan in 2018 is lowest among the NDVI from 2012 till 2018.

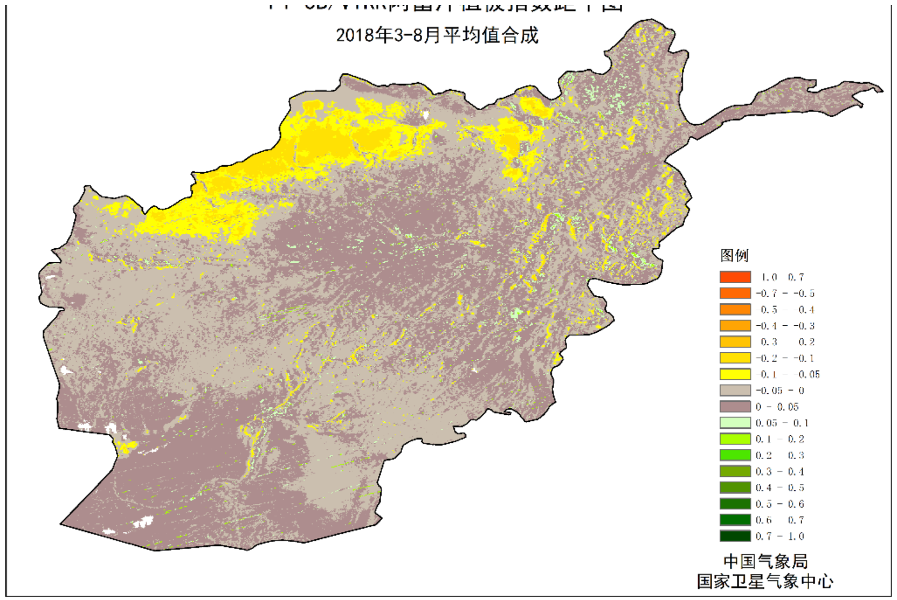
## Average NDVI of crop season(Mar-Aug, 2012-2017)



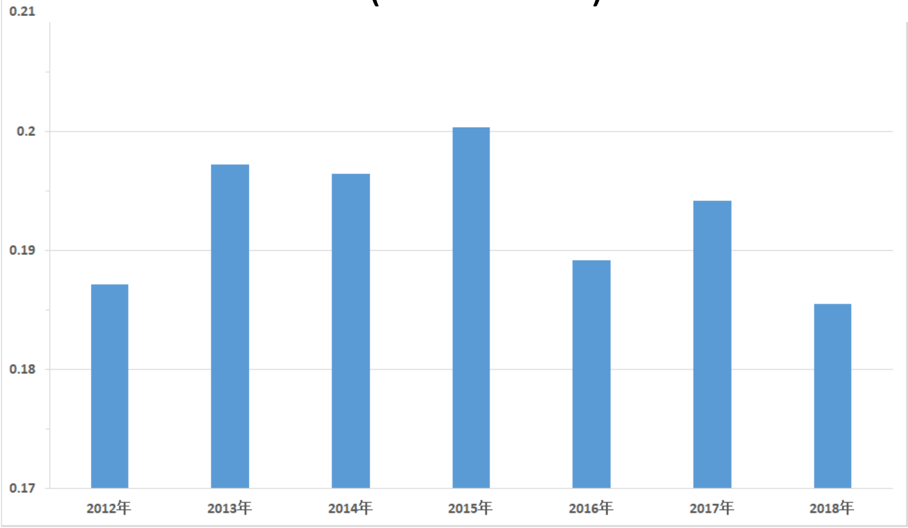

## Area of different level of NDVI during crop season(Mar-Aug, 2012-2017)



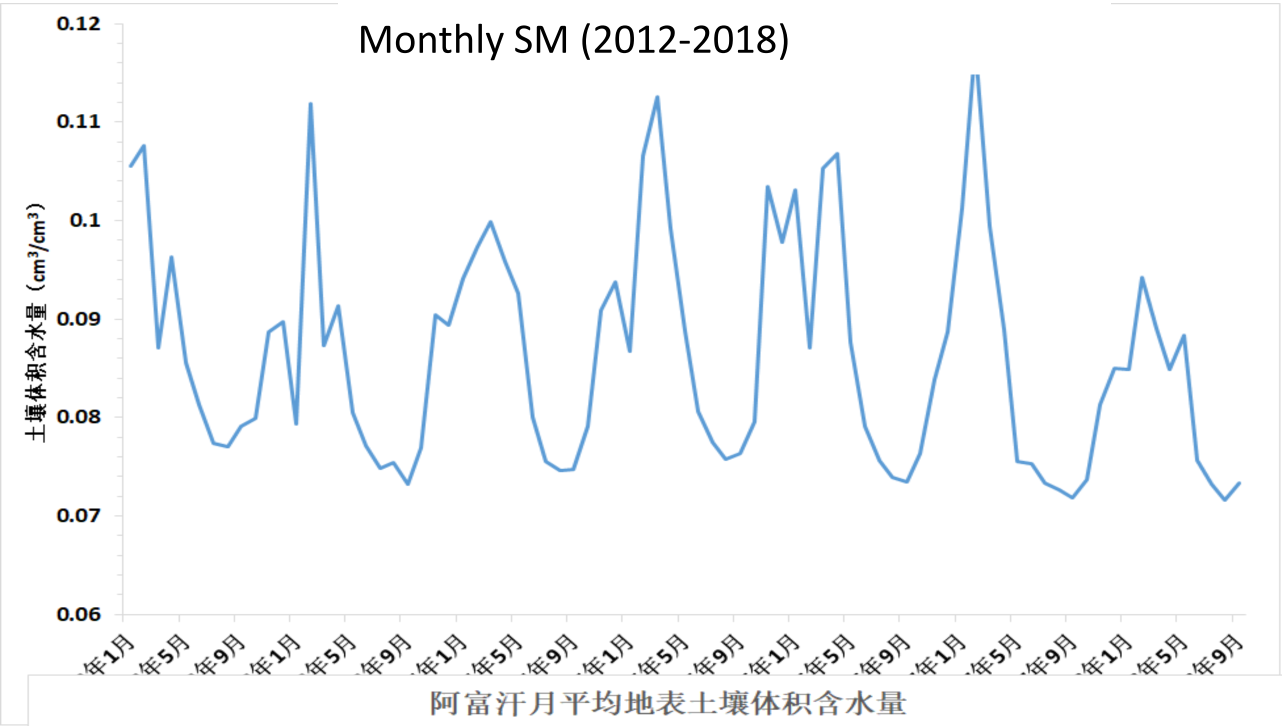

## Anomaly NDVI of crop season(Mar-Aug, 2018)



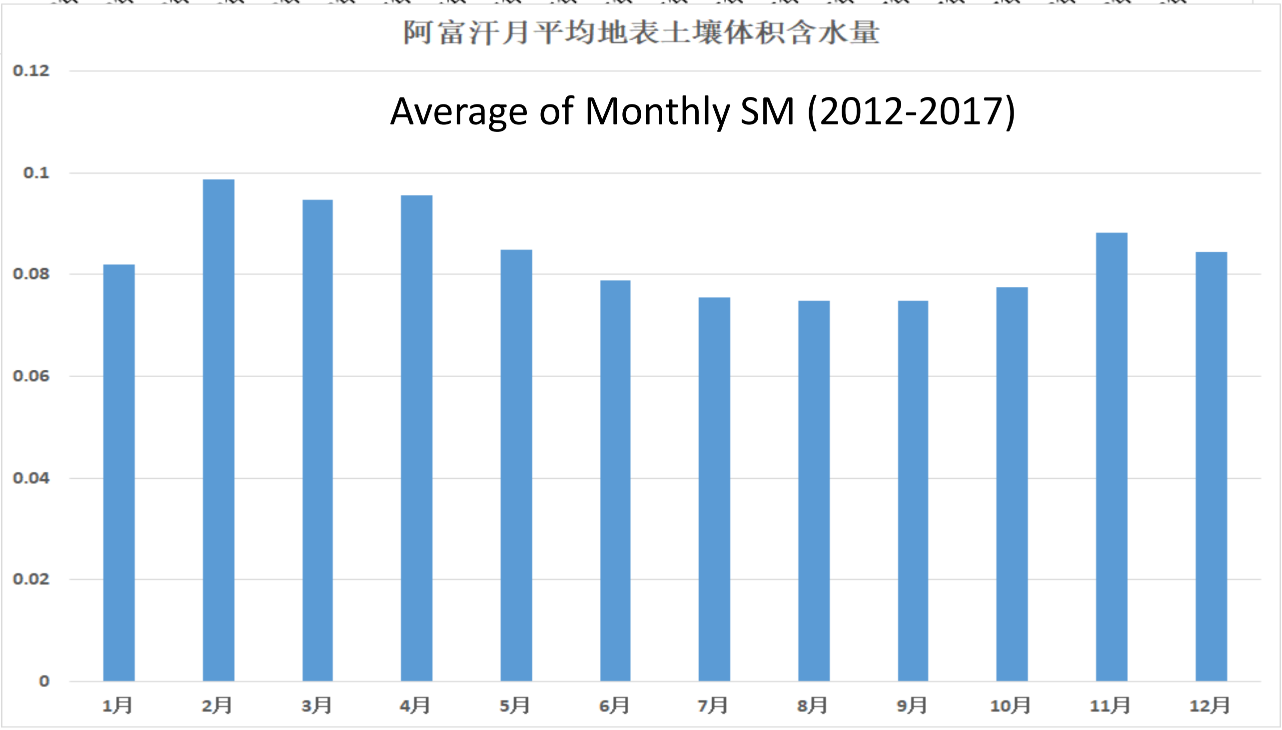

## Area of Average NDVI during crop season (2012-2018)



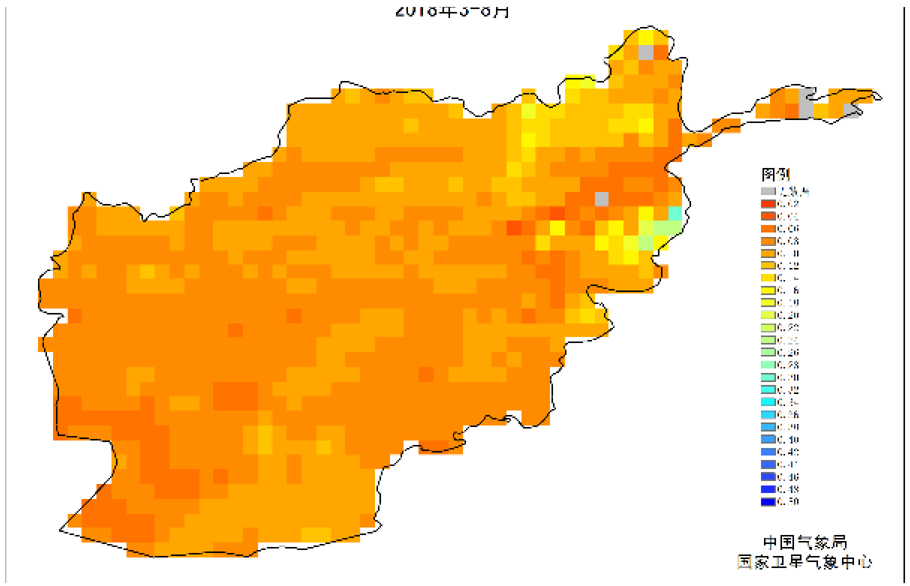
In general, the peak value of soil moisture appears from February to April, and the minimum value of soil moisture appears from August to September every year. The maximum soil moisture in Afghanistan in 2018 is significantly lower than that in other years.



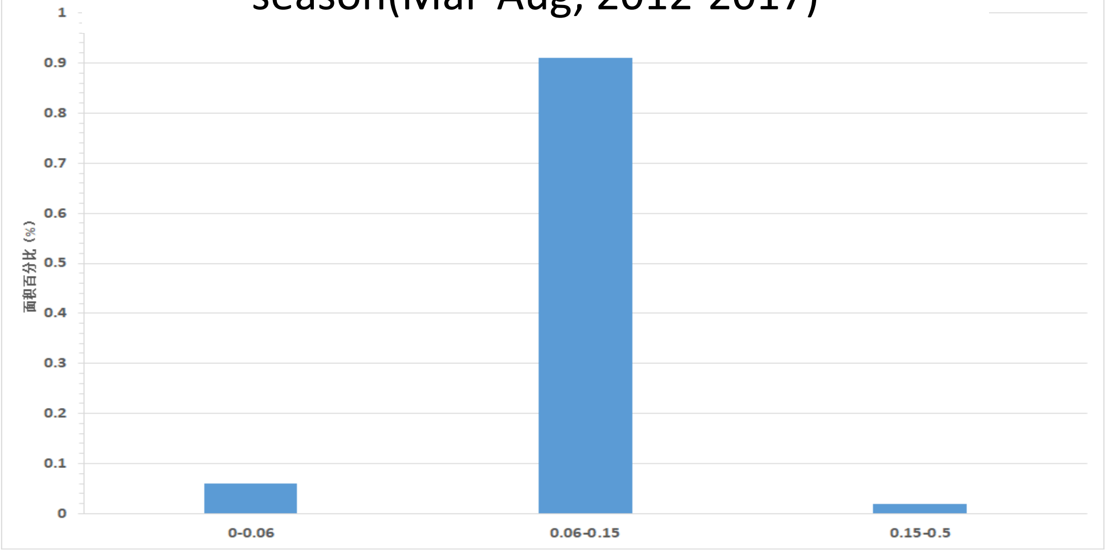

The soil moisture was generally low, There was no significant monthly variation. Higher soil moisture appears from February to April, and the lowest value appears from July to September



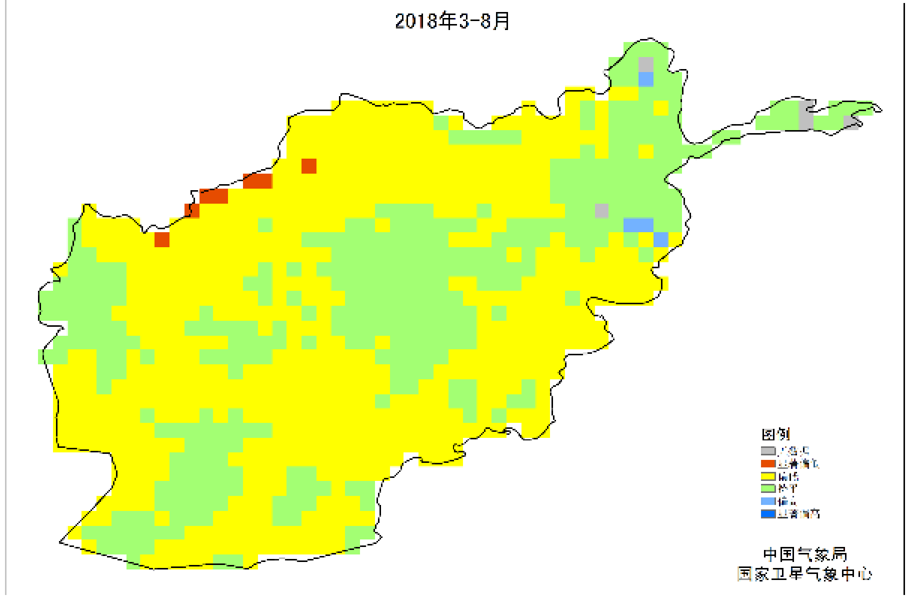
## Average SM of crop season(Mar-Aug, 2012-2017)



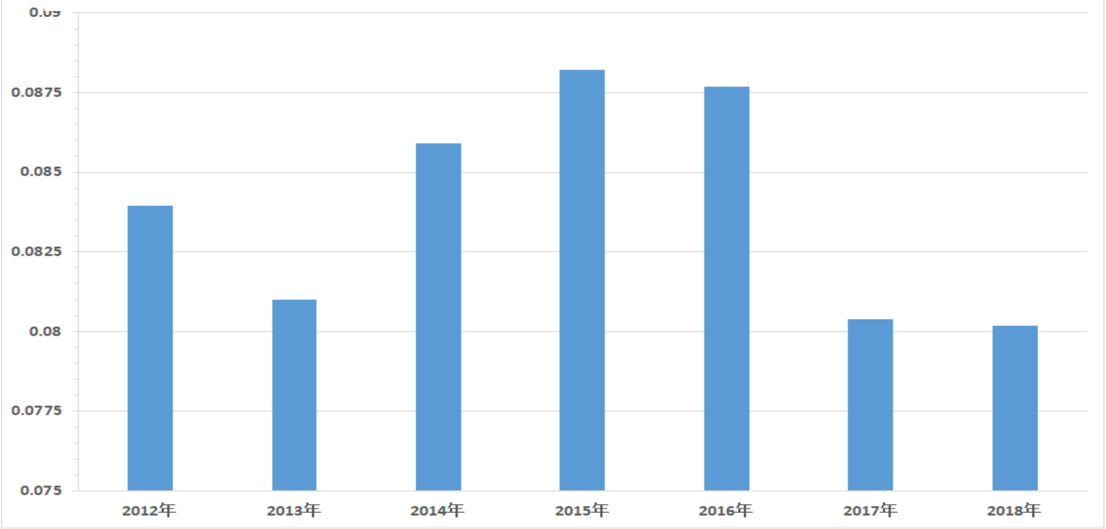

## Area of different level of SM during crop season(Mar-Aug, 2012-2017)




## Anomaly SM of crop season(Mar-Aug, 2018)




## Area of Average SM during crop season (2012-2018)



# Construct drought monitoring index based on FY-3/ SM

**soil moisture -- soil volume water content (absolute value);**

- Disadvantages: soil water holding capacity in different regions are different, and the same soil volume water content represents different degrees of dryness and wetness in different soil conditions.

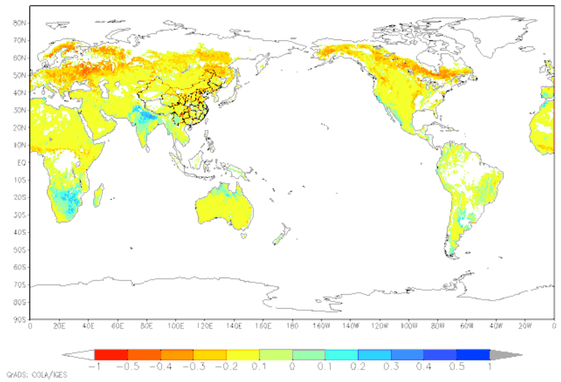
**The SM difference between some time and the same period of the previous year**

- Disadvantages: lack of stable reference

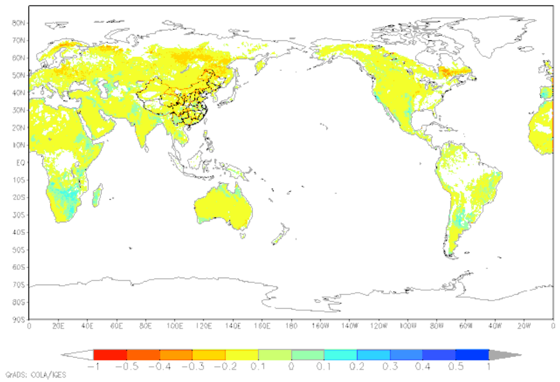
- The soil moisture product of FY-3/MWRI have for accumulated for 8 years of data since the launch of FY3B (2010.10).
- Based on the temporal series FY-3B / MWRI soil moisture data three indices are constructed:
- anomaly , anomaly percentage and normalized SM index ( Nindex);

$$\text{Nindex} = \frac{SM - SM_{min}}{SM_{max} - SM_{min}}$$

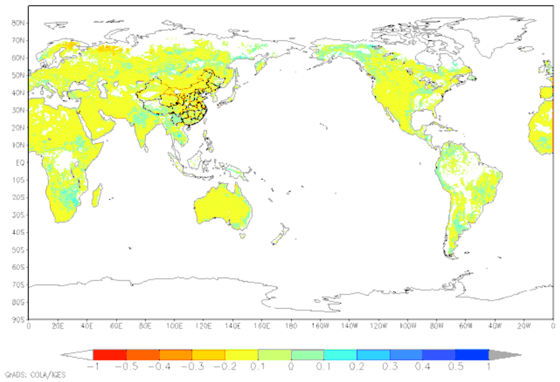
Glb_201705_1xun-anomaly



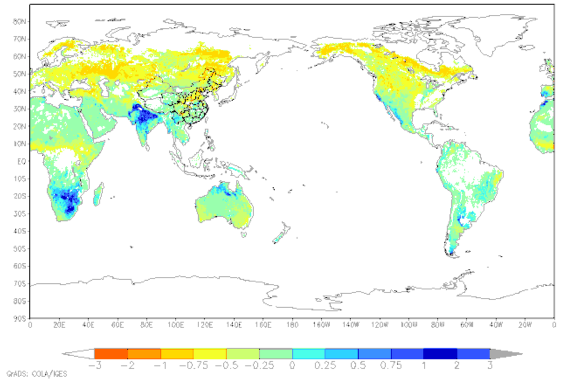
Glb_201705_2xun-anomaly



Glb_201705_3xun-anomaly



Glb_201705_1xun-anomalyPer



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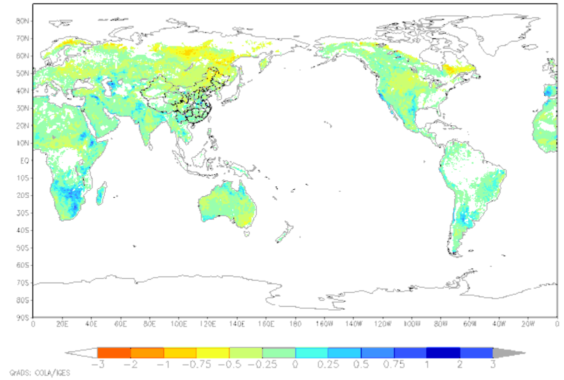

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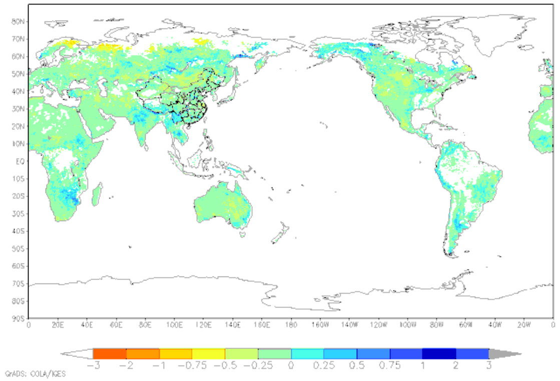
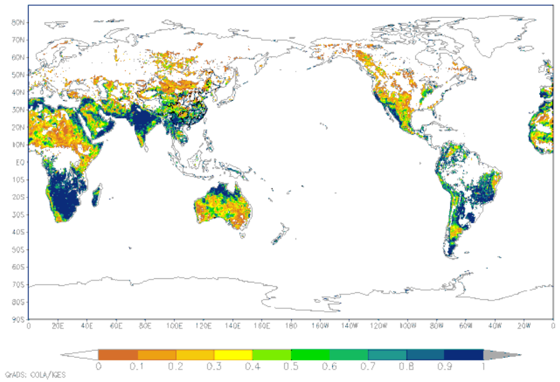


Glb_201705_1xun-Nindex



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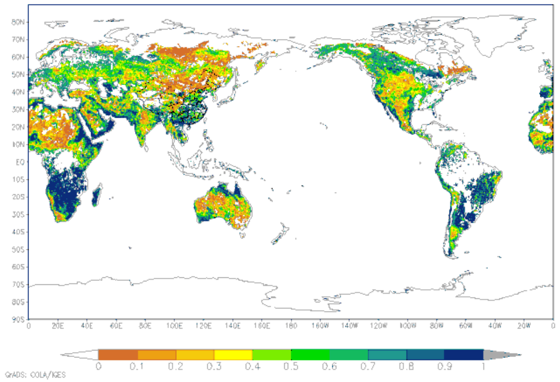

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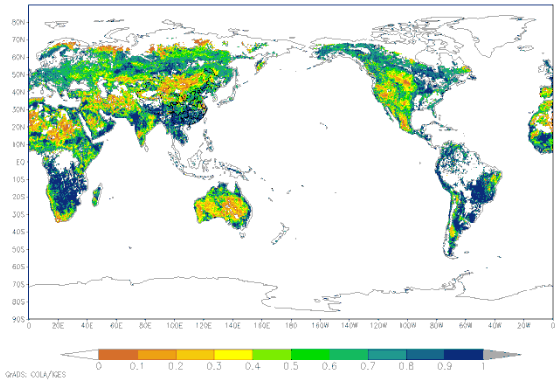
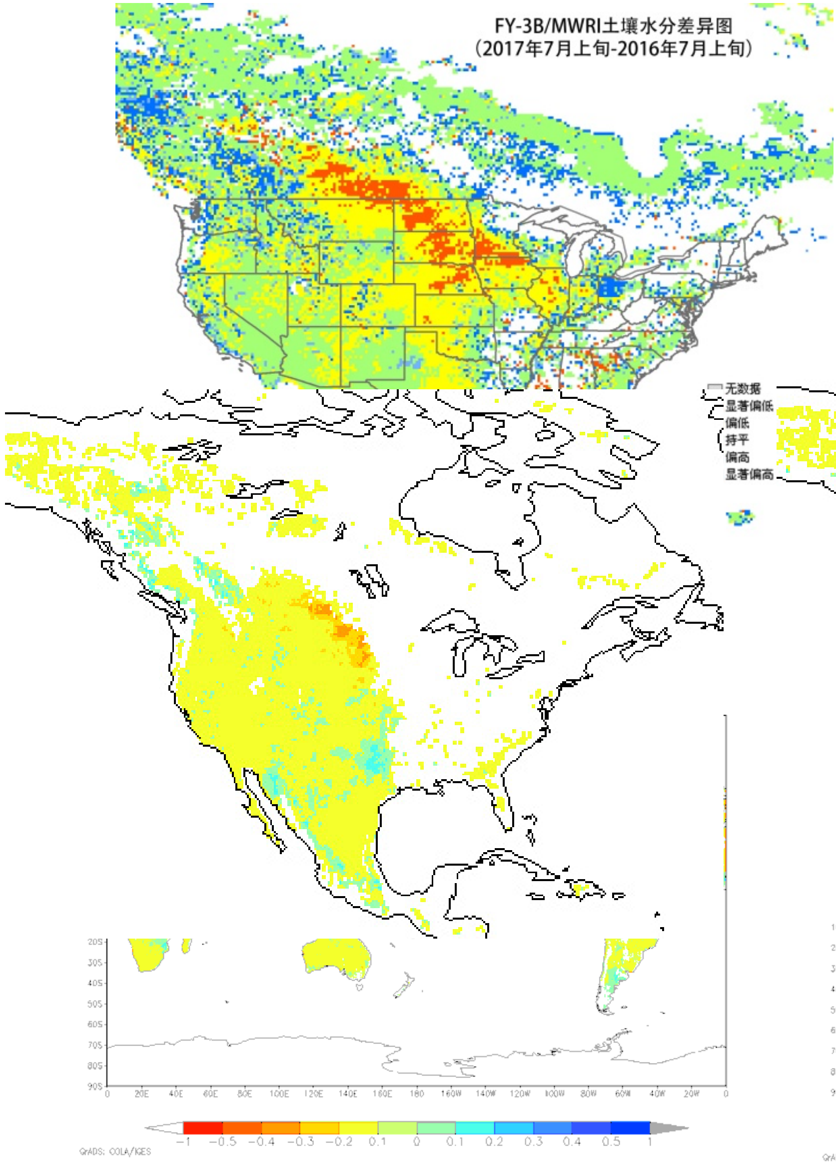
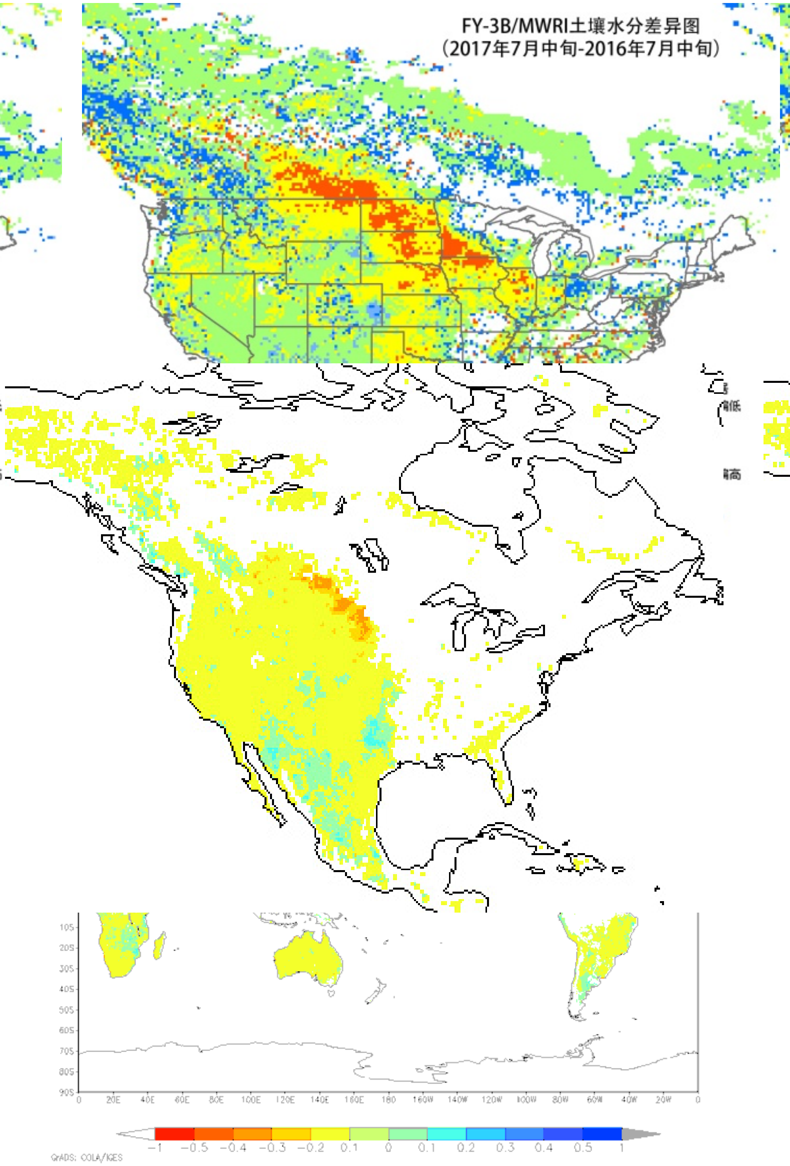
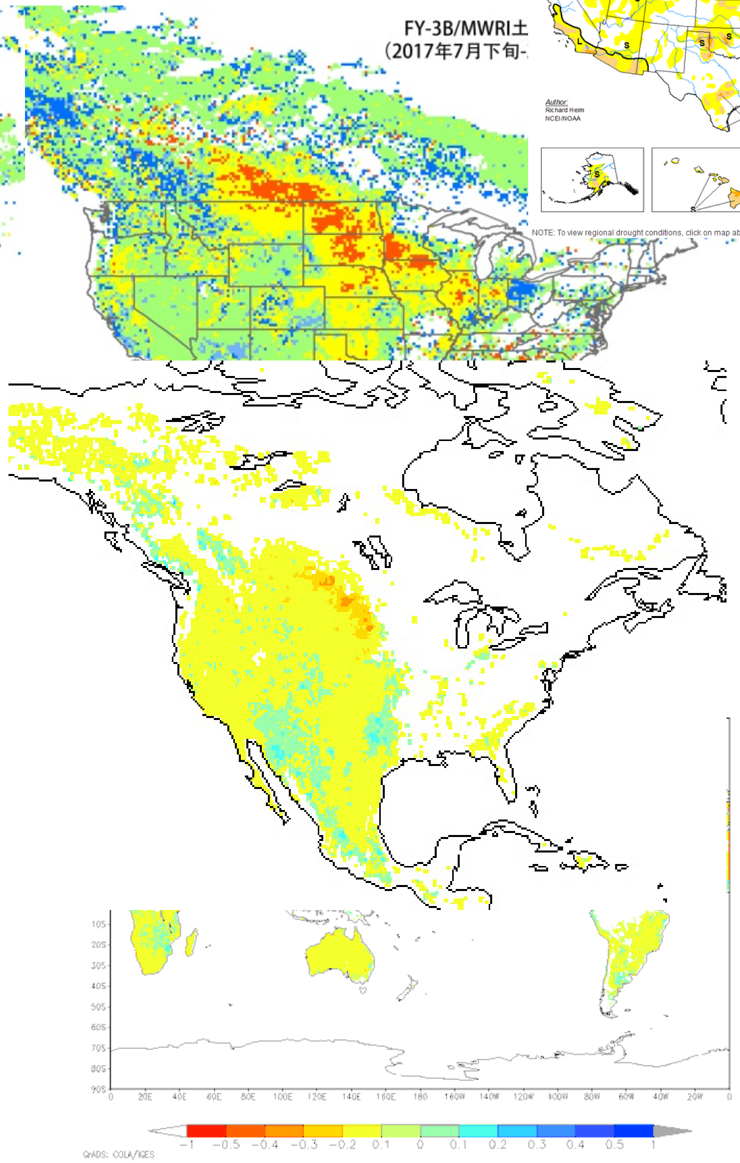
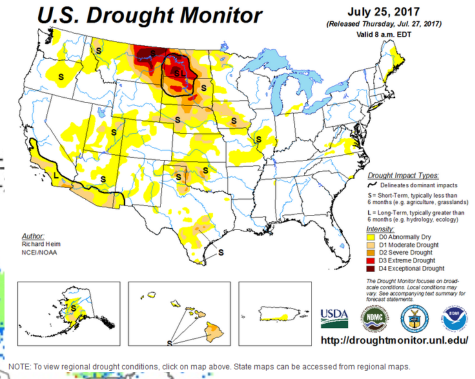


# Drought monitoring of USA, in Jul. 2017

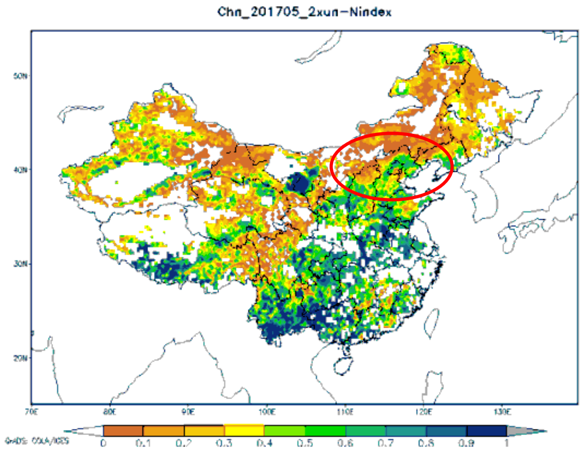


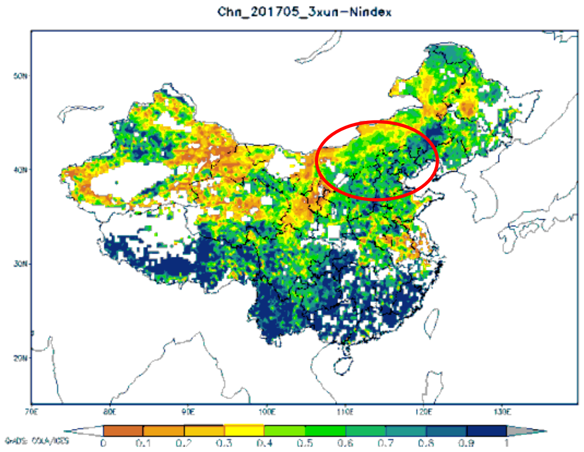



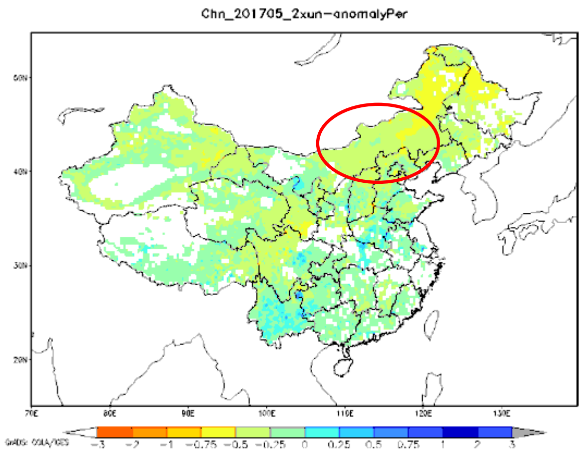



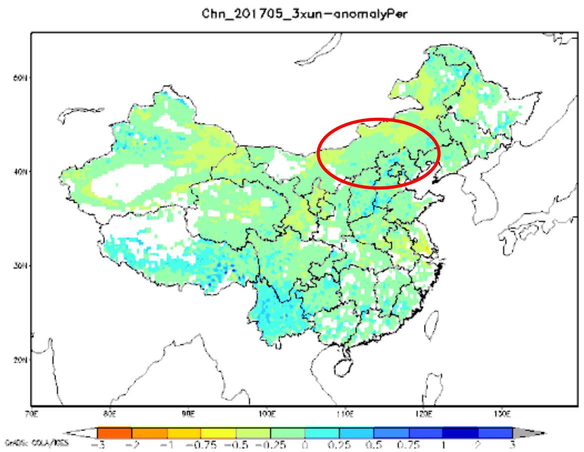



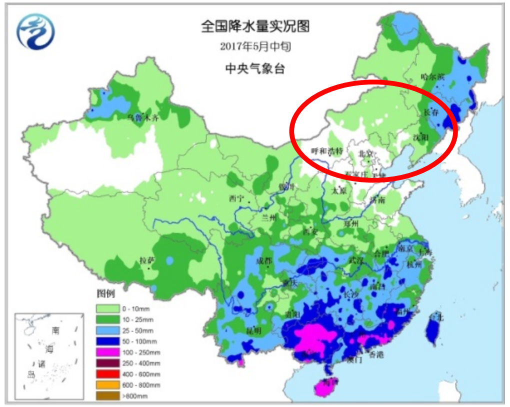
# Drought monitoring of Inner Mongolia, in May. 2017

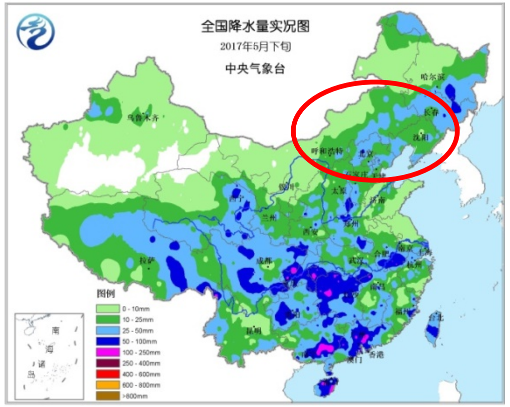


# Summary

- Using FY-3 NDVI product, The monitoring operation of global major crop growth and yield early forecast has been constructed in CMA.
- FY-3 data has been applied in crop area extraction and phenology monitoring in major producing area of China.
- FY-3 soil moisture, NDVI are applied in global drought monitoring event and shows good application prospect in global agriculture.
- How to determine the drought level and validate drought index based on FY-3/SM should be considered in the future work.

Thanks for your attention