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
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 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

**Remote sensing monitoring**

- **Advantages:**
  - High efficiency and fast update
  - Large observing area
  - Ability to represent the regional situation
  - Low cost

Effective supplement to the traditional methods, gradually become the main way of agricultural monitoring.
Agricultural remote sensing is an important application field of FY-3 satellite.

**demands**
- Many observation elements.
- Simultaneous observation is emphasized.
- High time resolution.
- Large observation width to ensure 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.
<table>
<thead>
<tr>
<th>Application Field in Agricultural Remote Sensing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crop planting area and mapping</strong></td>
</tr>
<tr>
<td>• crop planting area is an important basis for</td>
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<tr>
<td>the national food policy and economic plan.</td>
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<tr>
<td>It is necessary to acquire the area quickly</td>
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<tr>
<td>and accurately.</td>
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<tr>
<td><strong>Crop growth monitoring</strong></td>
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<tr>
<td>• monitoring indicators of crop growth mainly</td>
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<tr>
<td>include VI, LAI and biomass. VI is the</td>
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<td>most widely used.</td>
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<tr>
<td><strong>Crop yield estimation</strong></td>
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<tr>
<td>• three models of crop yield estimation of</td>
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<tr>
<td>remote sensing: empirical model, semi</td>
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<tr>
<td>mechanism model and mechanism model.</td>
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<tr>
<td><strong>Agricultural disaster monitoring</strong></td>
</tr>
<tr>
<td>• drought, flood, low temperature freezing</td>
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<tr>
<td>and disease remote sensing has developed</td>
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<tr>
<td>to meet the needs of global and regional</td>
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<td>scale agricultural information acquisition.</td>
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</tbody>
</table>
### FY-3B/VIRR NDVI

- **NDVI 10-day product**
  - **projection**: Hammer
  - **coverage**: Global(10°*10°)
  - **Spatial resolution**: 1km
  - **frequency**: Ten days monthly
  - **date range**: 2011.6-present

### FY-3D/MERSI NDVI

- **NDVI daily product**
  - **projection**: Geographic projection
  - **coverage**: global
  - **Spatial resolution**: 5km
  - **frequency**: daily

- **NDVI 10-day product**
  - **projection**: Geographic projection
  - **coverage**: global
  - **Spatial resolution**: 5km (1km), 250m
  - **frequency**: Ten days

- **NDVI monthly product**
  - **projection**: Geographic projection
  - **coverage**: global
  - **Spatial resolution**: 5km (1km), 250m
  - **frequency**: monthly

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

- **Product name**
- **projection**
- **coverage**
- **Spatial resolution**
- **frequency**

<table>
<thead>
<tr>
<th>Product name</th>
<th>projection</th>
<th>coverage</th>
<th>Spatial resolution</th>
<th>frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDVI segment product</td>
<td>———</td>
<td>5-minute segment</td>
<td>250m</td>
<td>5 minutes</td>
</tr>
<tr>
<td>NDVI daily product</td>
<td>Geographic projection</td>
<td>global</td>
<td>5km</td>
<td>daily</td>
</tr>
<tr>
<td>NDVI 10-day product</td>
<td>Geographic projection</td>
<td>global</td>
<td>5km (1km), 250m</td>
<td>Ten days</td>
</tr>
<tr>
<td>NDVI monthly product</td>
<td>Geographic projection</td>
<td>global</td>
<td>5km (1km), 250m</td>
<td>monthly</td>
</tr>
</tbody>
</table>
FY-3 products related to global agriculture monitoring - Soil Moisture

<table>
<thead>
<tr>
<th>RMSE</th>
<th>Heihe Station</th>
<th>Daman Station</th>
<th>Huazhai Station</th>
<th>Arou Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground vs FY3D</td>
<td>0.0641</td>
<td>0.0277</td>
<td>0.0282</td>
<td>0.1198</td>
</tr>
<tr>
<td>Ground vs SMAP</td>
<td>0.0722</td>
<td>0.0266</td>
<td>0.0309</td>
<td>0.1414</td>
</tr>
<tr>
<td>FY3D vs SMAP</td>
<td>0.0204</td>
<td>0.0201</td>
<td>0.0215</td>
<td>0.0628</td>
</tr>
</tbody>
</table>
Staple Crop area extraction
Phenology monitoring
Global major crop growth monitoring
Drought monitoring
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
Compared with the areas of last year, the winter wheat areas of Henan, Shandong, and Hebei in 2019 are the same as those in 2018. The area of Anhui and Hubei increased this year.

Using FY-3 data, we can extract several kinds of staple crops areas (winter wheat, corn, rice, etc.) dynamically, which can provide the basis for crop growth monitoring.
Area extraction of Other crops in Jiangsu Province

- rape
- winter wheat
- rice
- corn
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
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.
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.
Compared with the period of 2018, the regreening period of this year 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

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.

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

\[ VCI_j = \frac{NDVI_j - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \]

Where, \( VCI_j \) — 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, \( NDVI_{min} \) 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

- Winter wheat growth monitoring of Russia 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

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

corn growth monitoring of Brazil
Crop growth monitoring in global major producing area—Growth trend analysis

Wheat growth monitoring of India during growing season 2017 vs 2016

Soybeans growth monitoring of Brazil during growing season 2017 vs 2016

Soybeans growth monitoring of Argentina during growing season 2017 vs 2016

Soybeans growth monitoring of South America during growing season 2017 vs 2016
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.
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 RET
Oct. 2019

FY-2 Anomaly Percentage of RET
Oct. 2019

Last ten days of Oct. 2019

Last ten days of Oct. 2019
Improvement of drought monitoring methods and indicators

**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

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**Drought Monitoring**

**Improvement of drought monitoring methods and indicators**
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.

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

There is a weak process of rainfall, and the soil moisture has increased, drought relieved temporarily.
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 a severe drought.
Drought monitoring of USA----soil moisture difference
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.
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)

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

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

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.
The soil moisture product of FY-3/MWRI have 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);

\[
Nindex = \frac{SM - SM_{min}}{SM_{max} - SM_{min}}
\]

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.

Disadvantages: lack of stable reference

Construct drought monitoring index based on FY-3/SM
Drought monitoring of Inner Mongolia, in May. 2017
• 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