Institute of Remote Sensing and Digital Earth
Chinese Academy of Sciences

Agricultural Drought Monitoring from Global to Field

Nana Yan, Bingfang Wu, Sheng Chang

yannn@irsa.ac.cn

Institute of Remote Sensing and Digital Earth (RADI)
Chinese Academy of Sciences (CAS)

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- Global Drought Monitoring
- China Drought Monitoring
- Field Drought Monitoring
- Prospects

Drought Definition

More than 150 published definitions of drought in the academic literature were found.

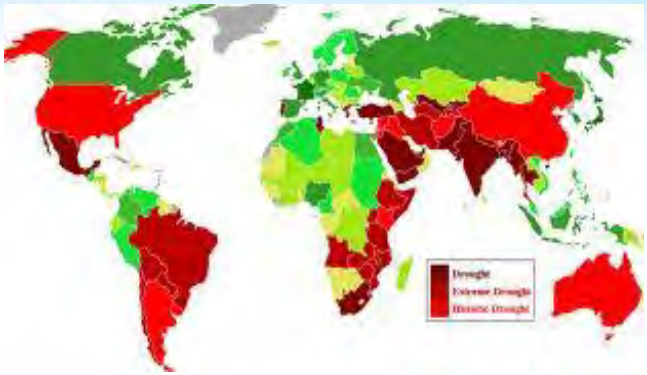
Meteorological drought: a prolonged period of below average precipitation

Agricultural drought: there is not enough moisture to support average crop production

Hydrological drought: water reserves in aquifers, lakes and reservoirs fall below an established statistical average

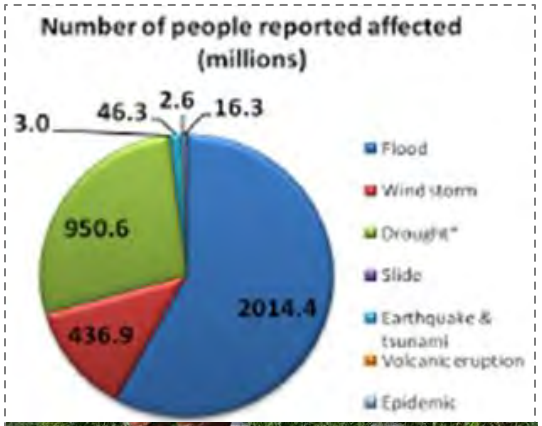
Background

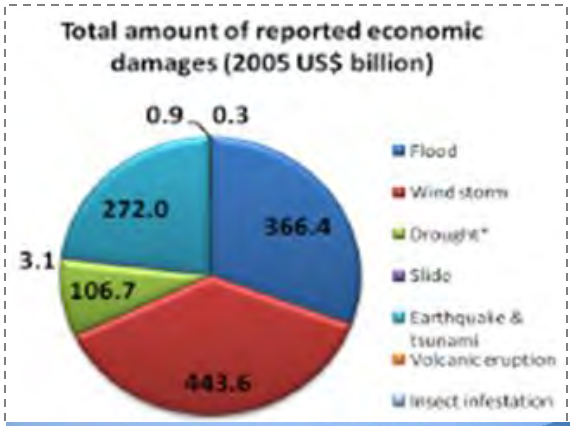
- Drought has happened in most areas of globe.
- Global drought affects more people and brings out large economic damages.

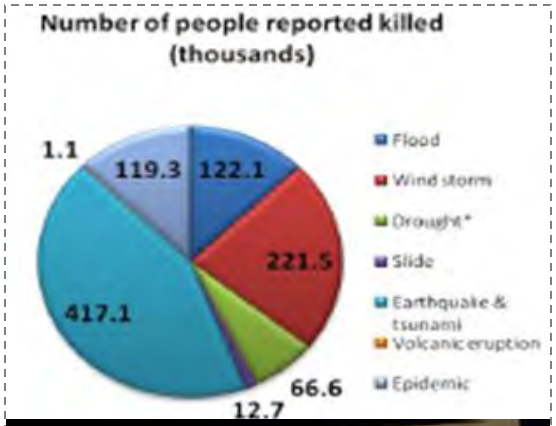


(source:unitedcats.wordpress.com)

Source: UN-ISDR (International Strategy for Disaster Reduction) – Period 1991-2005

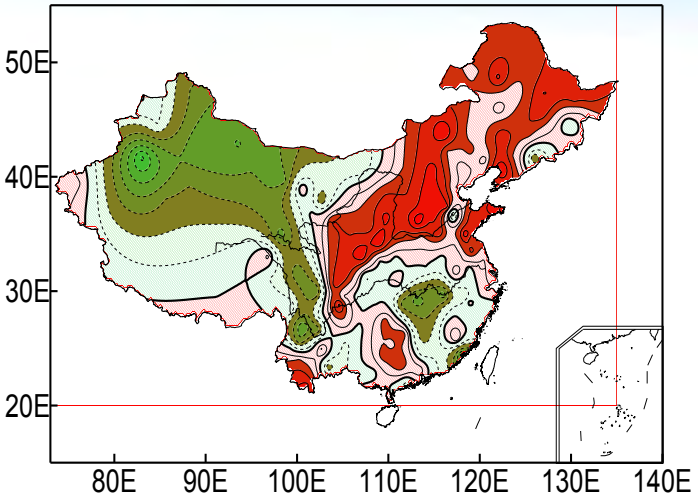




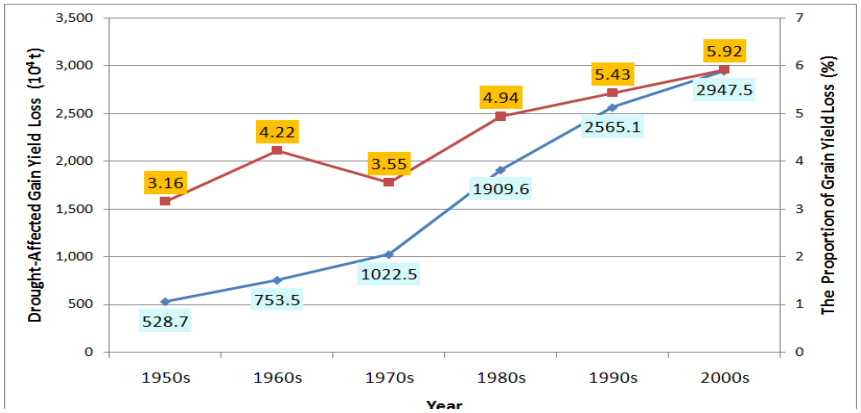


Background

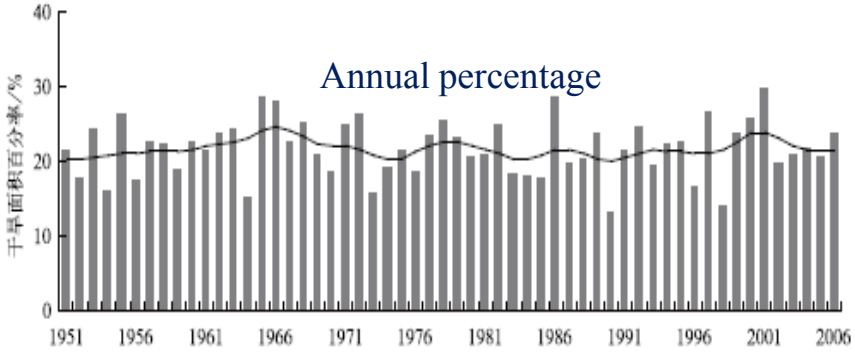
- High frequency of Drought in China, which gradually increased during 1951-2006
- Drought area is about 20% of the whole country annually
- In China, the grain yield loss due to drought is increasing significantly in recent 60 years.



Drought frequency 1951 – 2006
(Yang Guijun, 2011)



The grain yield loss affected by drought during different periods



Annual percentage of drought impact areas over China during 1951-2006

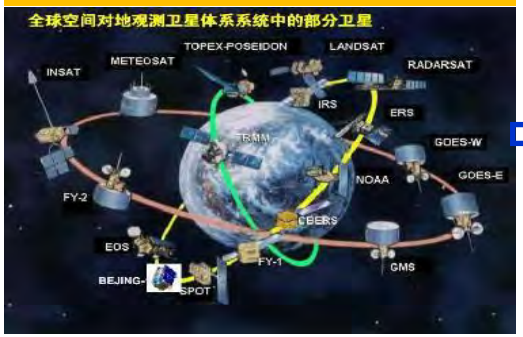
Drought characteristics

1) It builds over a period of time (may be even a year or two) with increased scarcity of water.
2) It does not have a well-defined start. It is a creeping phenomenon.
3) Drought may be localized covering a district or a group of districts, and even widespread covering a few provinces.
4) Drought intensity, duration and frequency may be different in a district or a piece of land.
5) Drought produces a complex and serious impacts in the economic, environmental and social respects.

How To Monitor Drought?

Methodology

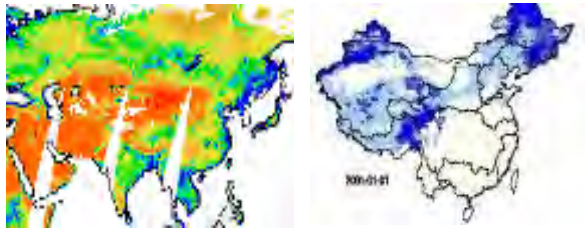
Multi-resource remote sensing



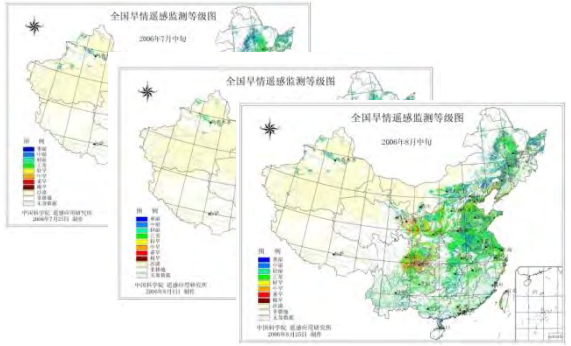
Field observation

Meteorological data

Data processing Drought Index calculating



Drought monitoring results



Outline

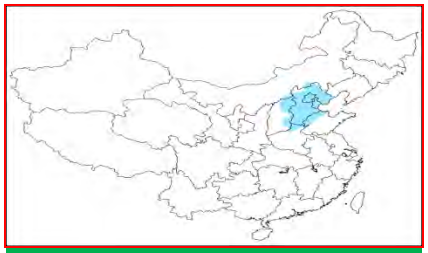
Global

Data:
- TRMM
- AMSR-E
- MODIS

Methodology:
- SPI /VHI
- SM anomaly
- VI anomaly

Temporal and spatial resolution:
- Monthly
- 25km

China

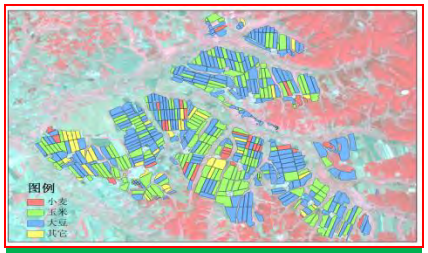


Data:
- MODIS 1B
- FY-3/MERSI

Methodology:
- VCI/TCI/VHI
- ESI/TANDVI
- SM anomaly

Temporal and spatial resolution:
- Ten-day
- 1km

Field



Data:
- HJ-1A/B CCD
- HJ-1 IRS
- TM/SPOT

Methodology:
- NDWI
- ESI

Temporal and spatial resolution:
- variable
- 30m/10m

Precipitation Index

Precipitation deficit reflects the drought conditions.

Data sources:

- TRMM satellite precipitation Products(1998-2013)

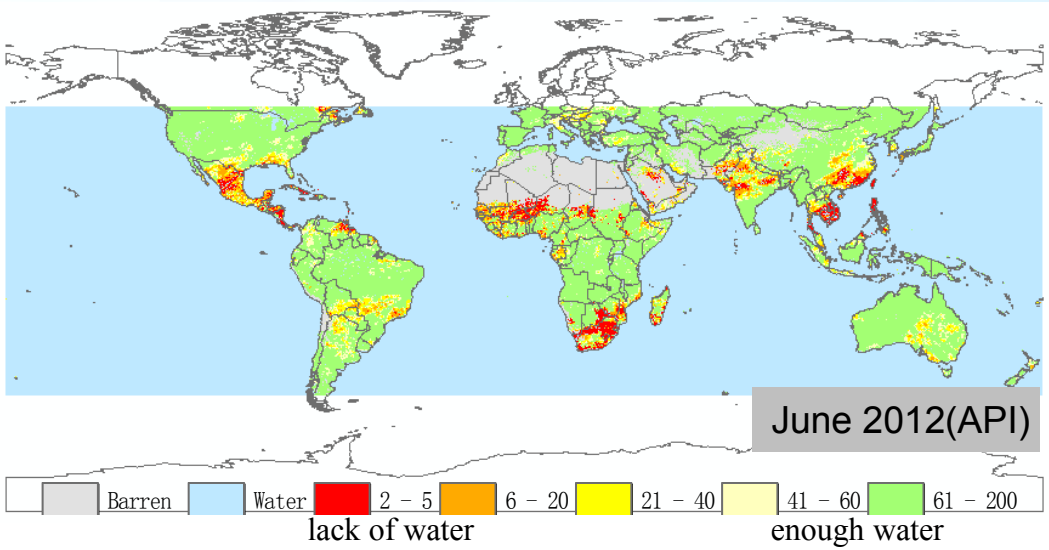
Methods:

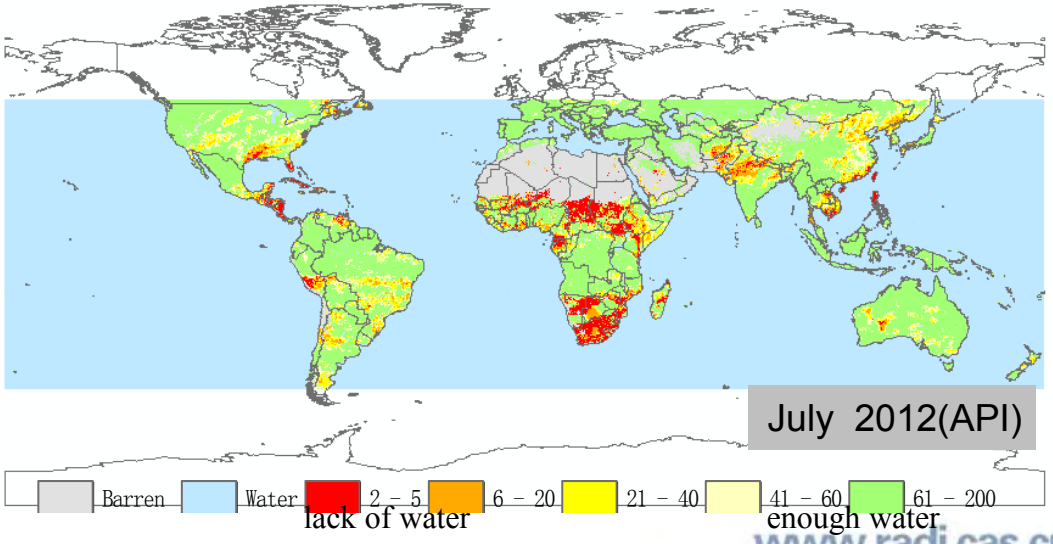
- Anomaly Precipitation Index

$$API = \frac{P - \overline{P}}{\overline{P}} * 100\%$$

- Standardized Precipitation Index

$$SPI = \frac{X_i - X_m}{\sigma}$$





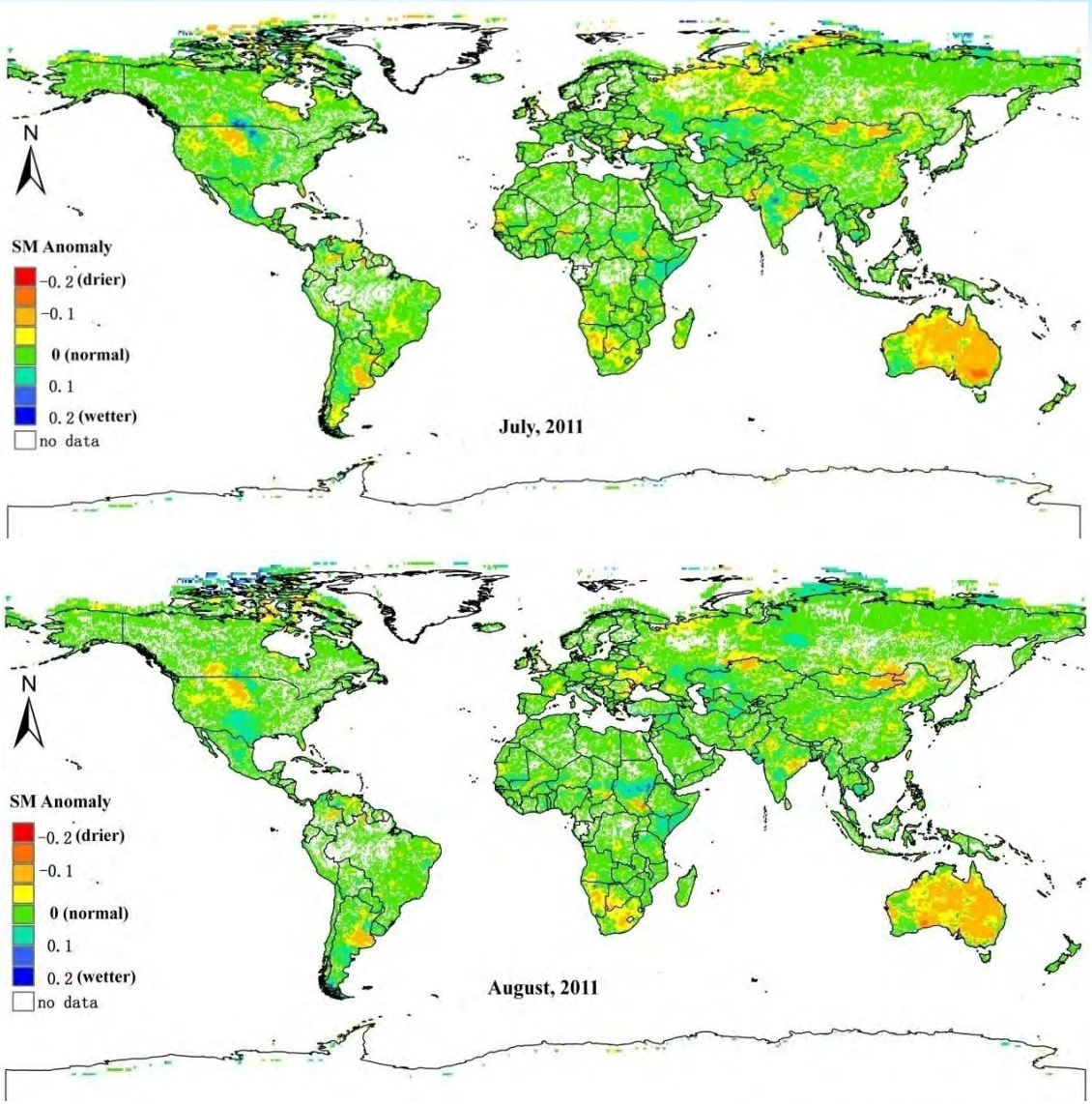
Soil Moisture Anomaly

Data sources:

- Soil moisture product from AMSR-E of AQUA
- Soil moisture Product from MWRI of FY-3

Methods:

- Data processing and consistence analysis between two products
- Developing the long time series SM products(from AMSR-E and MWRI data)
- Calculating the soil moisture departure



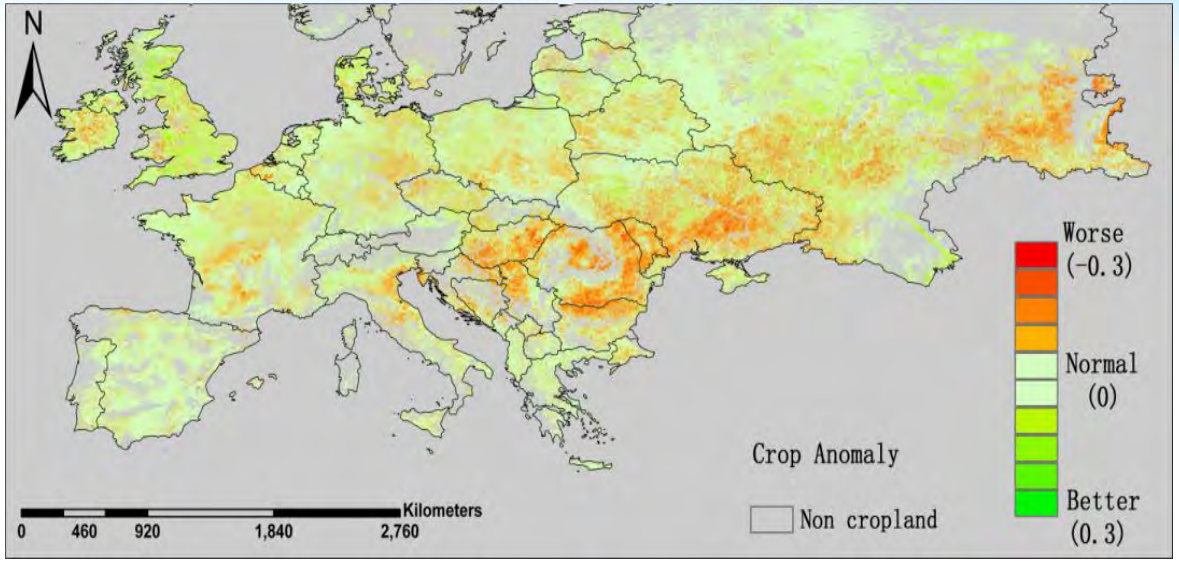
NDVI anomaly

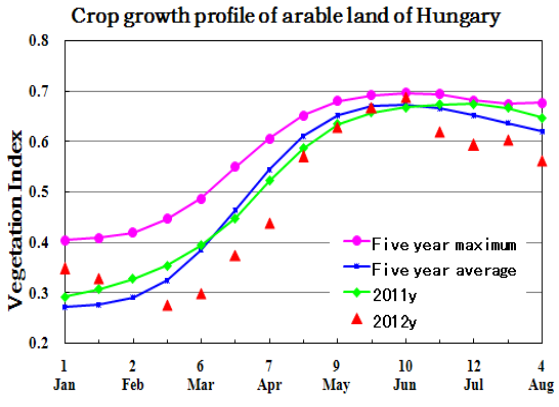
Data sources:

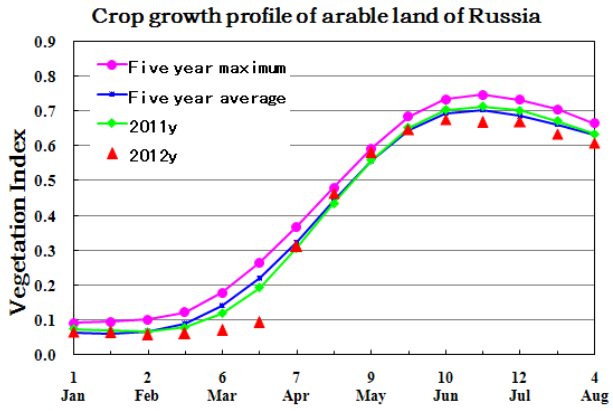
- MODIS/AUQA NDVI 16-day Product(2002-2012)
- MODIS/TERRA NDVI 16-day Product(2000-2012)

Methods:

- The NDVI anomaly is used for crop condition and drought monitoring in the Global.
- The NDVI anomaly is calculated by the NDVI of the same month in different year.





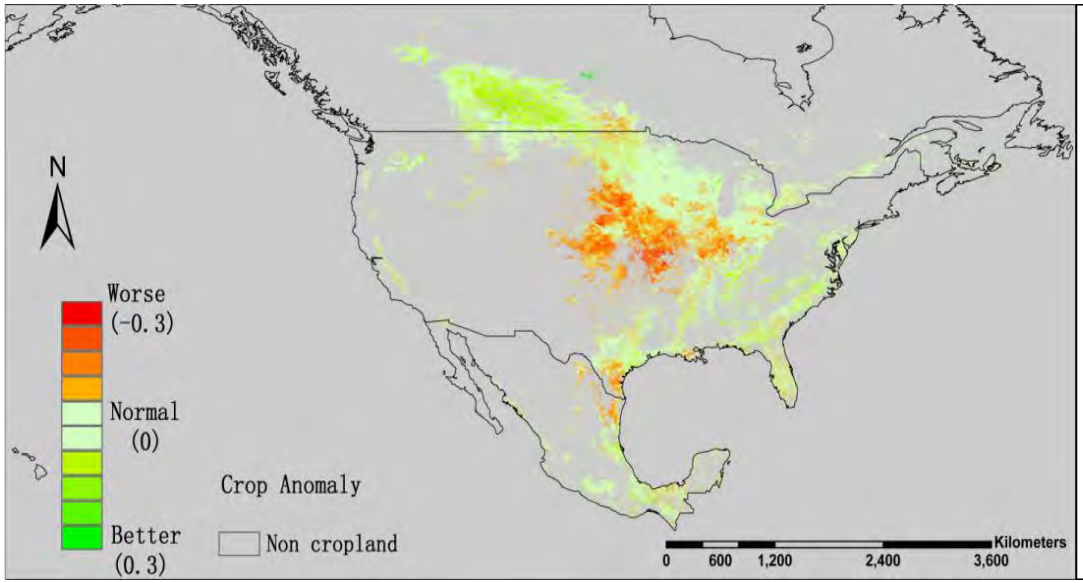


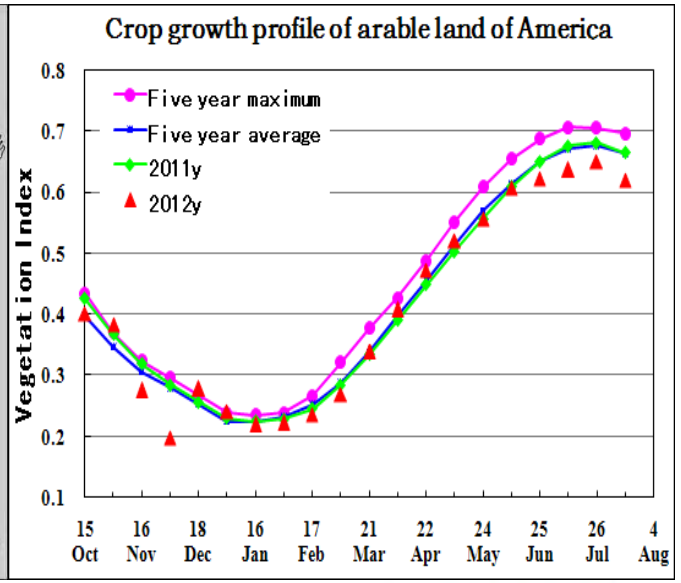
As to the European drought, crop condition in August 2012 is worse than 2011 in the south of Russia, the center and north of Italy, the south-west of Hungary, and the south of Romania.

NDVI anomaly

North American drought, August, 2012

- Due to the constant drought, Crop condition across US in August 2012 is a little worse than 2011.
- Crop condition in August 2012 is better than 2011 in south-east of US, and south of Canada.
- Crop condition in August 2012 is worse than 2011 in the center of US and north-east of Mexico.



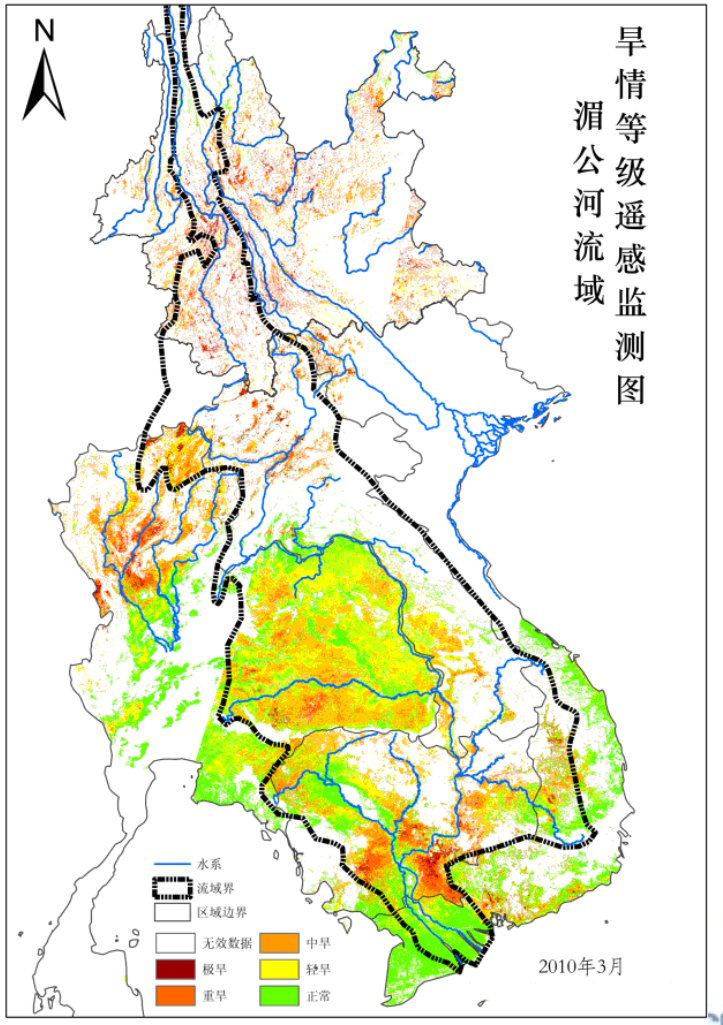


Vegetation Health Index(VHI)

The Mekong River Basin Drought, March, 2010

- the severe drought happened in the Mekong River Basin in early March.
- China area of the Basin suffered the most severe drought with about 80% of the arable land, which was more serious than other countries.

Country's area of the Basin	Ratio of drought to whole cultivated land	Ratio of severe drought to whole cultivated land
China	**79.3%**	**60.1%**
Thailand	48.2%	13.7%
Laos	33.3%	15.0%
Cambodia	45.1%	26.2%
Vietnam	48.3%	27.8%



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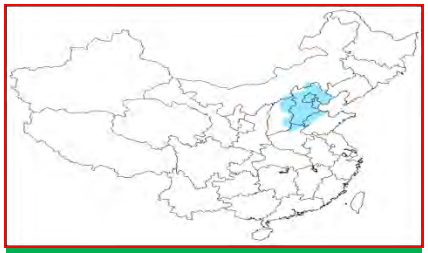

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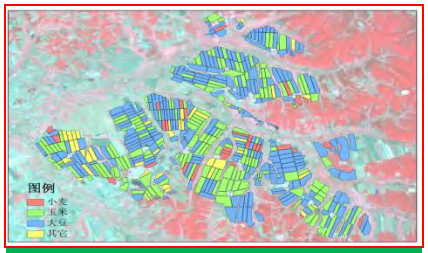

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- NDWI
- ESI

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- 30m/10m

Method-VCI&TCI&VHI

Vegeatation Condition Index

$$VCIj = \frac{NDVI_j - NDVI_{min}}{NDVI_{max} - NDVI_{min}} * 100\%$$

Temperature Condition Index

$$TCIj = \frac{T_{max} - Ts_j}{T_{max} - T_{min}} * 100\%$$

Vegetation Health Index

$$VHI = a * VCI + (1 - a) * TCI$$

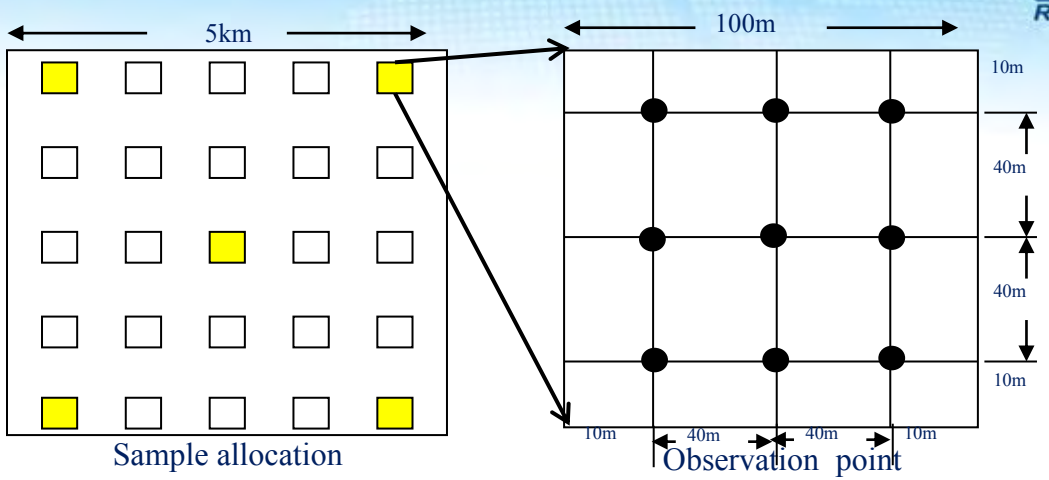
NDVIj NDVI of date j； NDVImax and NDVImin are the maximum and minimum NDVI of all dataset ; Tmax and Tmin are the maximum and minimum Ts of all dataset.

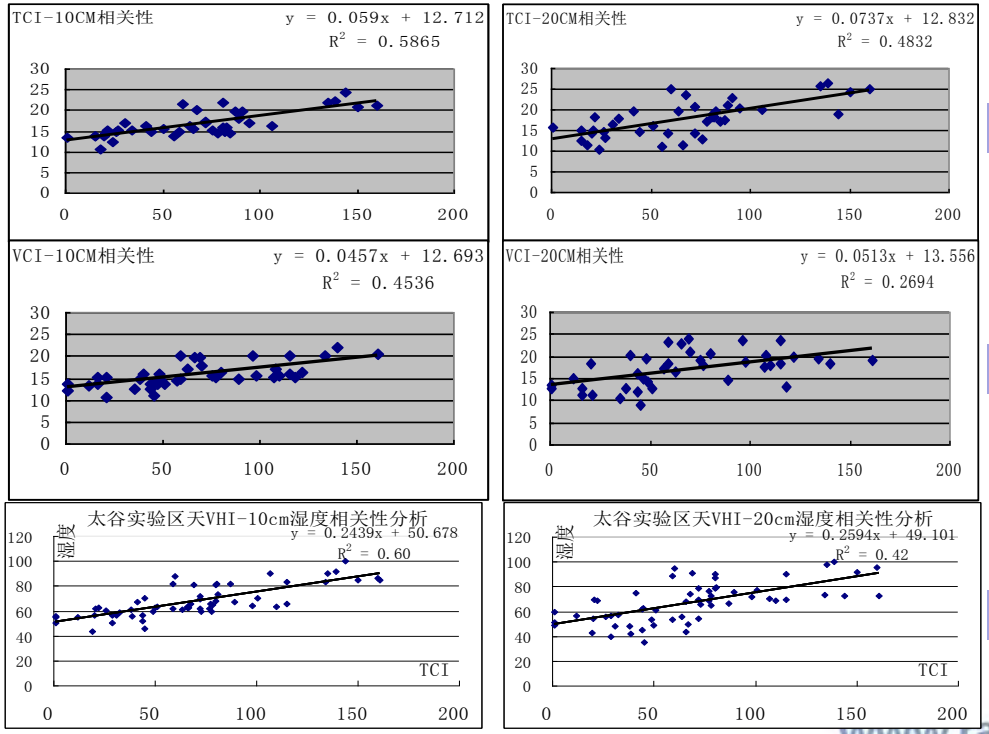
Validation at Taigu Site

- Indices(VCI/TCI/VHI), 2003-2005, day and ten-days
- Day soil moisture, 2003-2005, two depth of 10CM and 20CM
- Ten-days soil moisture, 2003-2005

- The relation between indices and soil moisture:

  VHI > TCI >VCI



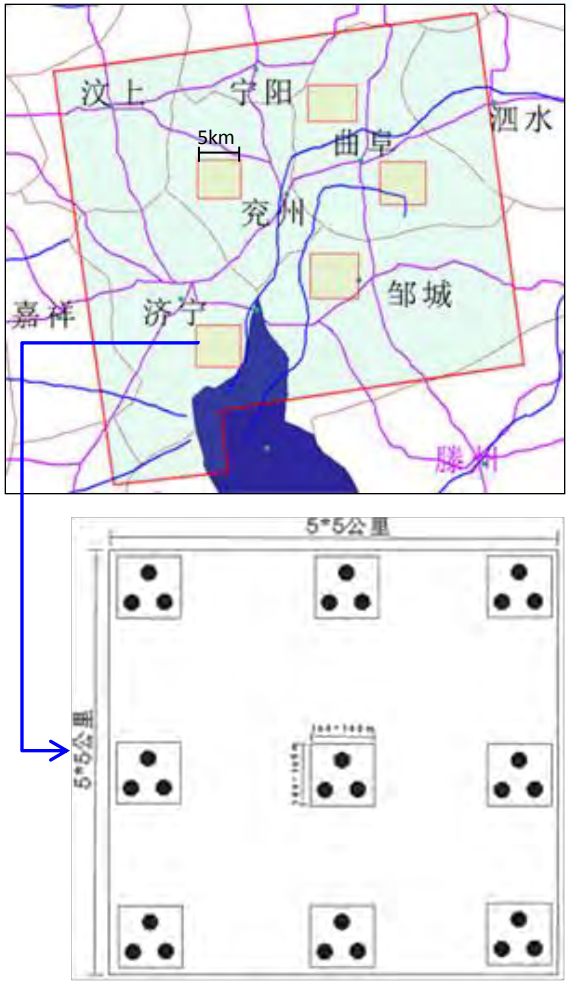


Validation at Jining Prefecture

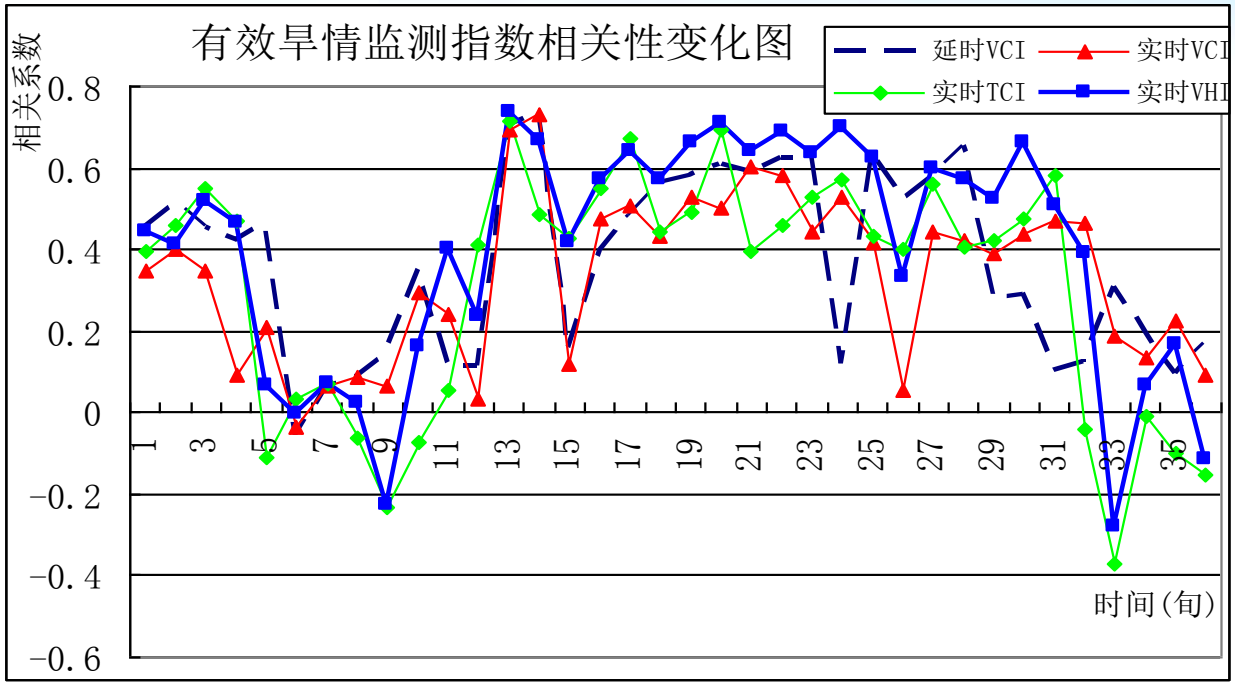
- Study area: Jining, Shandong
- Time: April-May 2005
- Relation analysis: indices and soil moisture
- The relation between indices and soil moisture:

  VHI > TCI >VCI

Depth	TCI_R^2	VCI_R^2	VHI_R^2
10cm Soil moisture	0.93	0.66	0.97
20cm Soil moisture	0.91	0.60	0.92



Validation in Shanxi Province



Soil moisture data from 70 stations and drought indices in 2003-2005 were used to analysis:

- VHI have high relation with soil moisture in the growth season of crop,
- Especially, during crop growth seasoning of April to October,VHI has good preformance,
- TCI is good for Nov-March, winter season

Country Wide Drought Indices Suitability

区划号	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月		1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月
1	TH	TW	TH	TW	TH	TH	HW	HW	TH	TW	TH	TH	111	TH	TW	TW	TW	TH	HW	TH	VH	TW	TW	TH	TW
2	TH	TW	TH	TW	TH	TH	HW	HW	TH	TW	TH	TH	112	TH	TW	TW	TW	TH	HW	TH	VH	TW	TW	TH	TW
3	TH	TW	TH	TW	TH	TH	HW	HW	TH	TH	TH	TH	113	TH	TH	TH	HT	TH	TH	HT	HT	VH	TH	TH	TW
4	TH	TW	TH	TW	TH	TH	HW	HW	TH	TH	TH	TH	114	TW	TW	HW	HT	HW	VH	HW	VT	TW	HW	TH	TW
5	TH	TW	TH	TW	TH	TH	HW	HW	TH	TW	TH	TH	115	TH	TW	TW	TW	TH	HW	TH	VH	TW	TW	TH	TW
6	TH	TW	TH	TW	TH	TH	HW	HW	TH	TH	TH	TH	116	TH	TW	TW	TW	TH	HW	TH	VH	TW	TW	TH	TW
7	TH	TW	TW	TW	TH	HW	TH	HW	VH	TH	TH	TH	117	TH	TW	TW	TW	TH	HW	TH	VH	TW	TW	TH	TW
8	TH	TW	TH	TW	TH	TH	HT	HW	HT	HT	TH	TH	118	TH	TH	TH	HT	TH	TH	HT	HT	VH	TH	TH	TW
10	TH	TW	TH	TW	TH	TH	HT	HW	HT	HT	TH	TH	119	TH	TW	TW	TW	TH	HW	TH	VH	TW	TW	TH	TH
11	TH	TW	TH	TW	TH	TH	HW	HW	TH	TW	TH	TH	120	TW	TH	TH	HT	HT	TH	HT	HT	HW	HW	TH	TH
12	TH	TW	TW	TW	TH	HW	TH	HW	VH	TH	TH	TH	121	TH	TW	TW	TW	TH	HW	TH	VH	TW	TW	TH	TH
13	TH	TW	TW	TW	TH	HW	TH	HW	VH	TH	TH	TH	122	TW	TW	HW	HT	HW	VH	HW	VT	TW	HW	TH	TH
14	TH	TW	TH	TW	TH	TH	HW	HW	TH	TH	TH	TH	123	TH	TH	TW	HW	TH	VH	HW	TH	HT	TH	TH	TH
15	TH	TW	TH	TW	TH	TH	HT	HW	HT	HT	TH	TH	124	TW	TH	TH	HT	HT	TH	HT	HT	HW	HW	TH	TH
16	TH	TW	TW	TW	TH	HW	TH	HW	VH	TH	TH	TH	125	TH	TW	TW	TW	TH	HW	TH	VH	TW	TW	TH	TH
17	TH	TW	TW	TW	TH	HW	TH	HW	VH	TH	TH	TH	126	TH	TH	TH	HT	TH	TH	HT	HT	VH	TH	TH	TH
18	TH	TW	TH	TW	TH	TH	HW	HW	TH	TH	TH	TH	127	TW	TH	TH	HT	HT	TH	HT	HT	HW	HW	TH	TH
..	TH	TW	TW	TW	TH	HW	TH	HW	VH	TH	TH	TH	.....	TW	TH	TH	HT	HT	TH	HT	HT	HW	HW	TH	TH
109	TH	TW	TW	TW	TH	HW	TH	HW	VH	TH	TH	TH	218	TH	TW	TW	TW	TH	HW	TH	VH	TW	TW	TH	TH

Drought Zone for China (218)

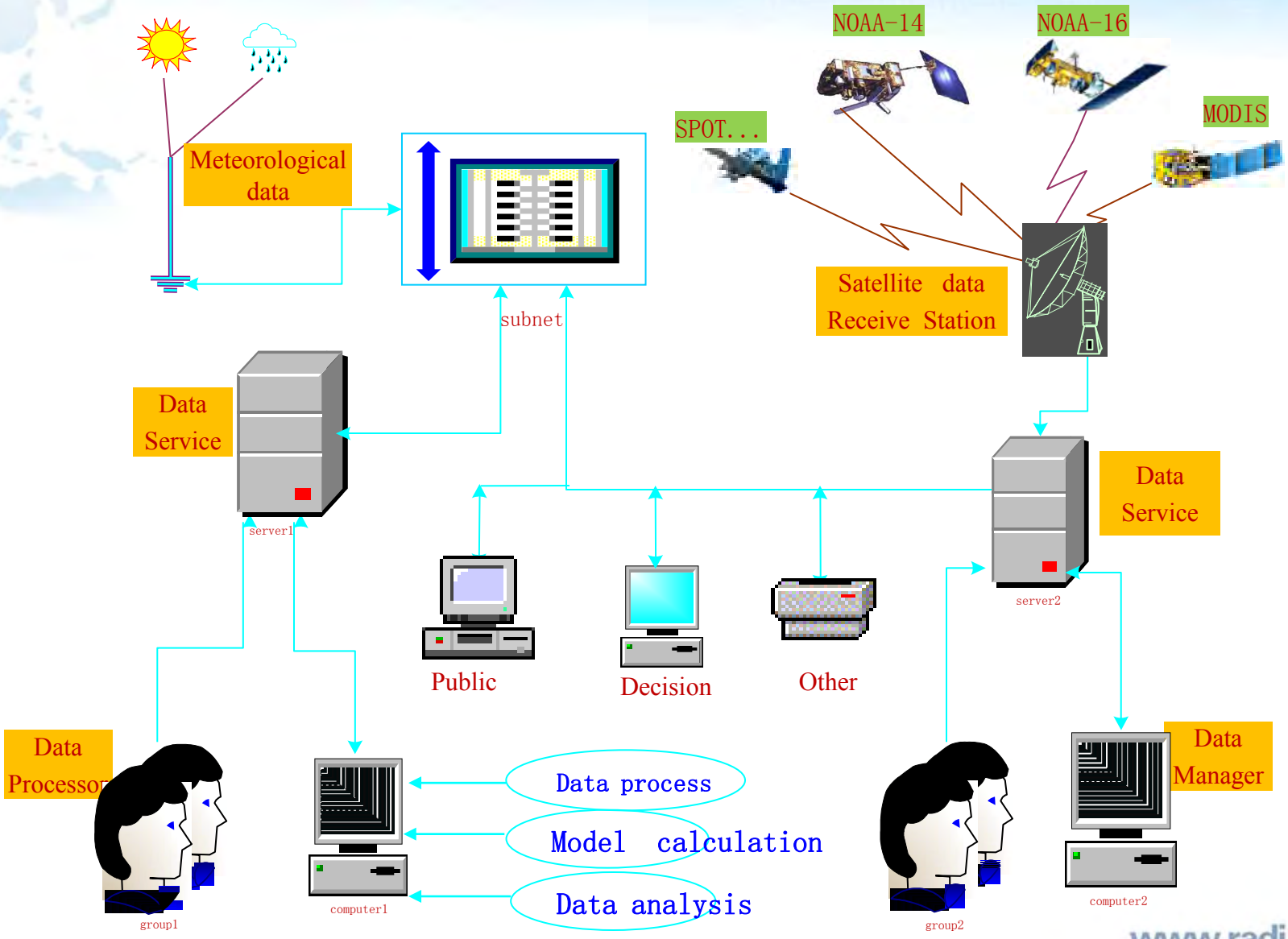
- The suggested index was presented in the table for each district in different months after the analysis of indices & soil moisture.
- The adjacent result was applied to the district due to the absence of in-situ soil moisture data.

Monitoring system

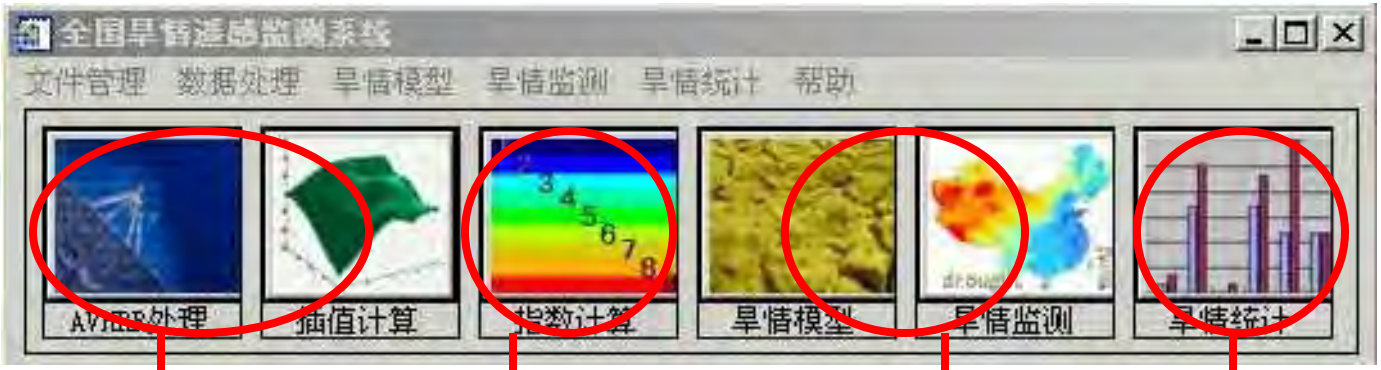
- Established at Ministry of water resources

- Meteorological Drought (5 indices) (1996-)
  - Rainfall Anomaly Index (RAI)
  - Annual Rainfall Anomaly Index (ARAI)
  - Deciles (DECILE)
  - Standardized Precipitation Index (SPI)
  - Palmer Drought Severity Index (PDSI)
- Agriculture Drought (DroughtWatch) (2 indices) (2005-)
  - Vegetation Condition Index (VCI)
  - Temperature Condition Index(TCI)
  - Vegetation Health Index(VHI)
  - Normalized Difference Water Index(NDWI)
- Hydorlogical Drought (4 indices) (2000-demon; 2005-operation)
  - Soil Moisture Index(SMI) SMI=SM/FC
  - Soil Moisture Anomaly Percentage Index (SMAPI) SMAPI=SM/SMavg

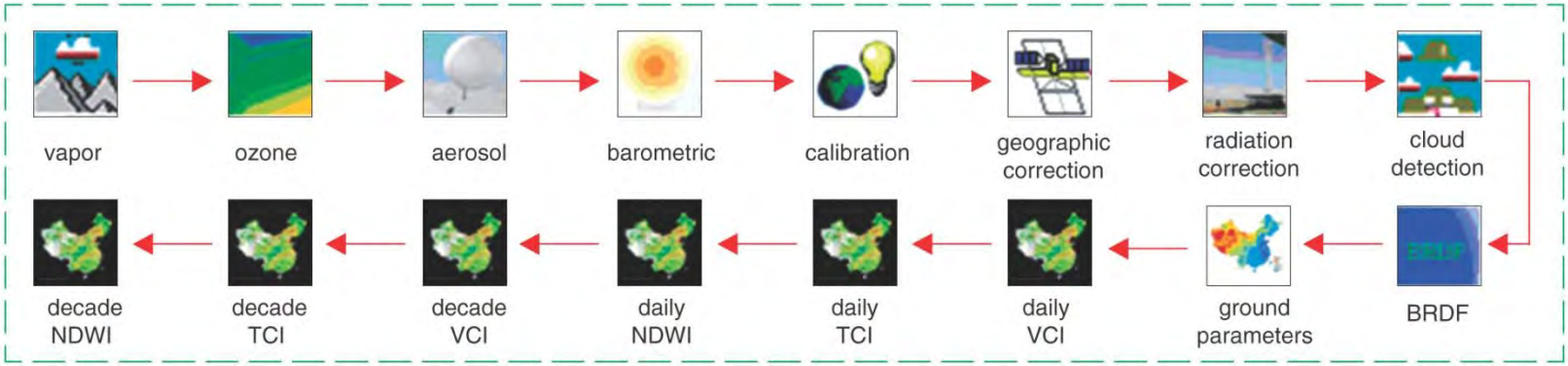
DroughtWatch Architecture



DroughtWatch System

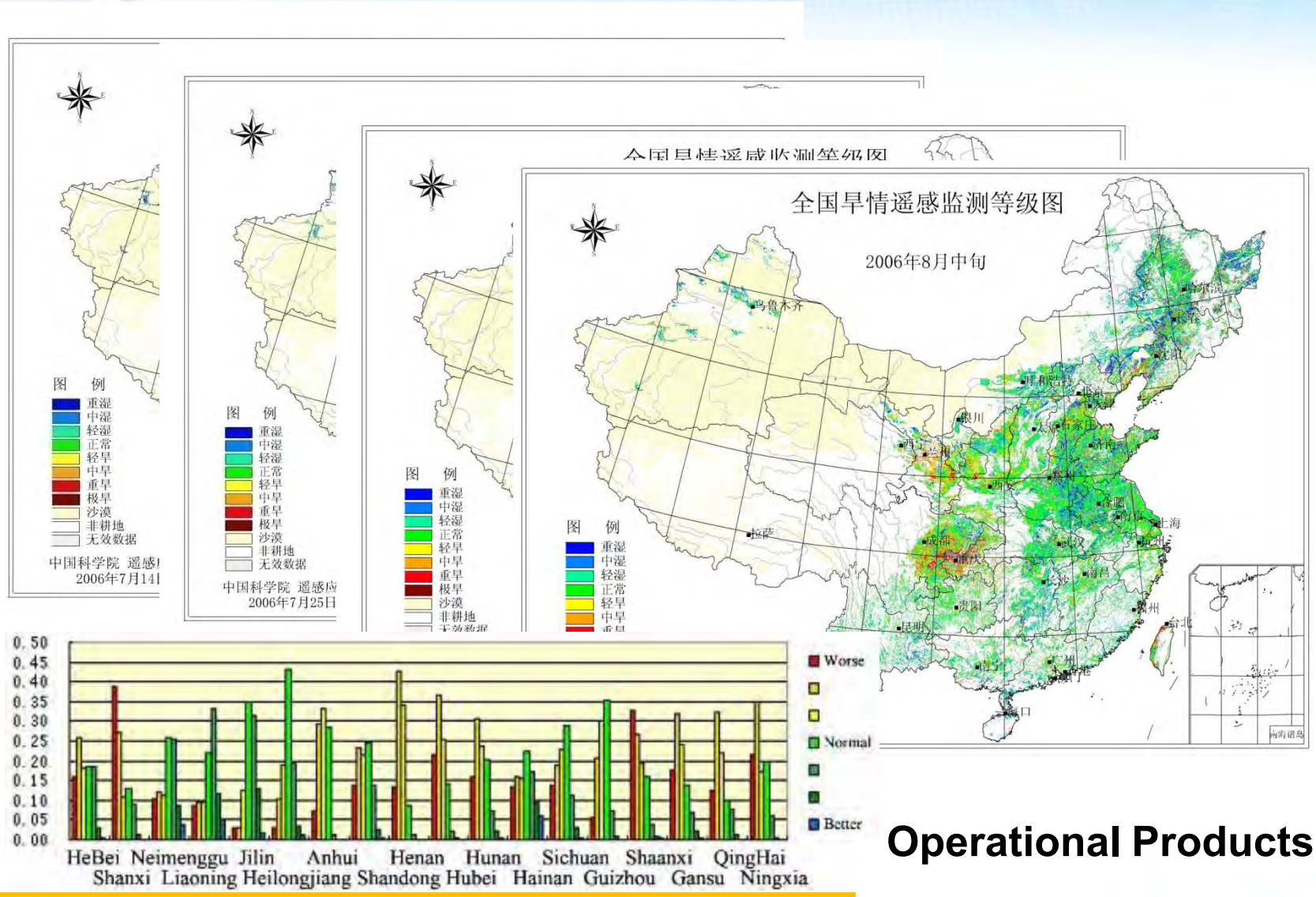


Pre-processing → **Drought Index** → **Drought monitoring** → **Statistics**



Upgrading: AVHRR to MODIS; MODIS to MERSI

DroughtWatch Products

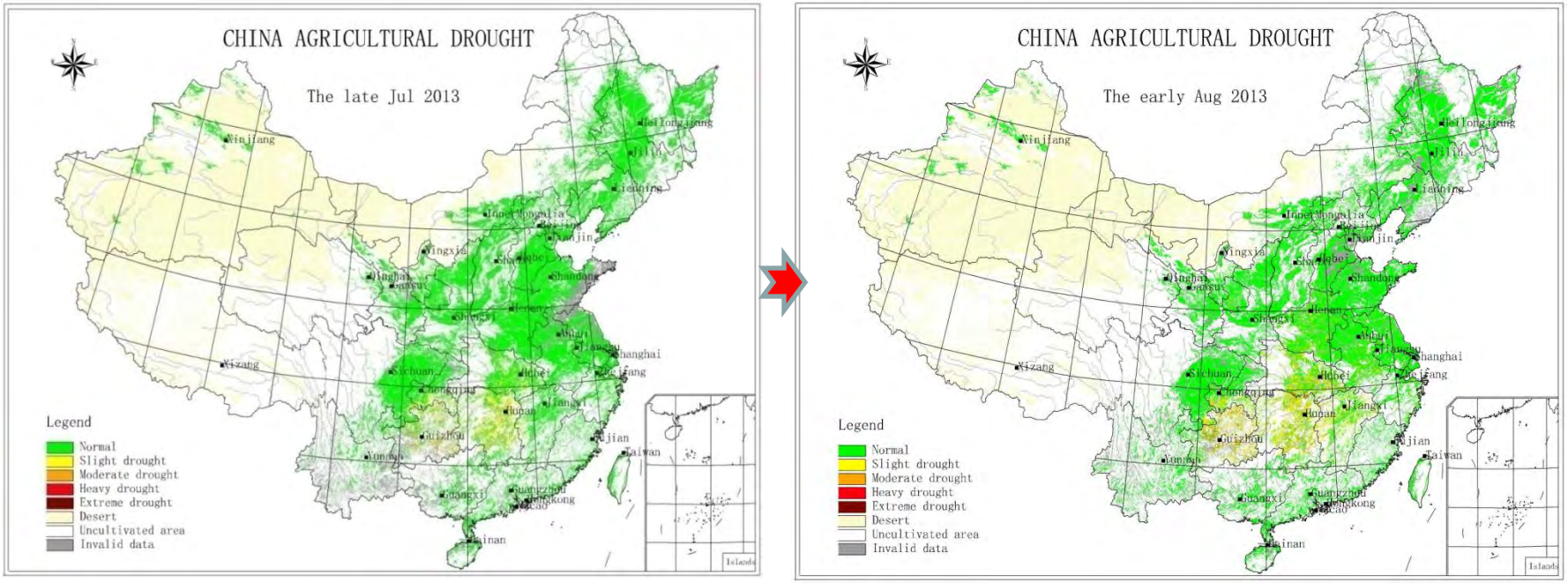


Operational Products

Percent of different drought grads in different provinces of China (April, 2006)

Applications

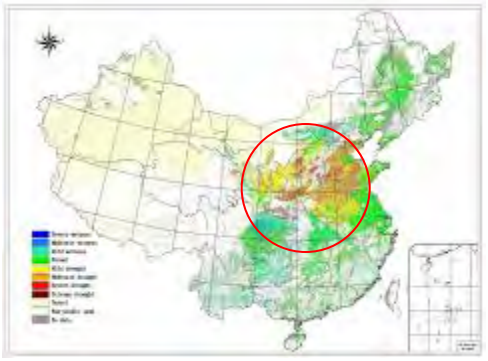
- From June 2013, the long-time extreme high temperature and low precipitation in parts of the south of China resulted in the constant drought.
- In the late July, about 2% of the arable land suffered from the drought (mainly moderate to mild) in the whole country.
- Up to August, the ratio of drought land to the whole land has increased to above 5%.



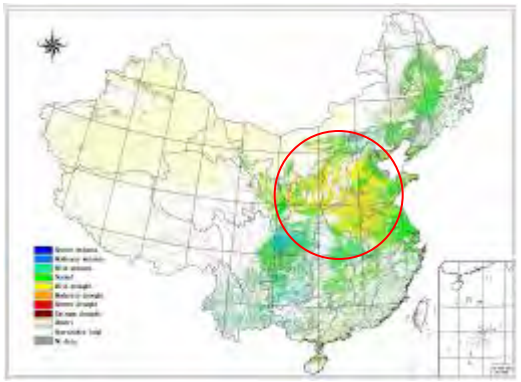
South of China in July-August, 2013

Applications

Drought monitoring in North Plain in early spring, 2009



January 21-31

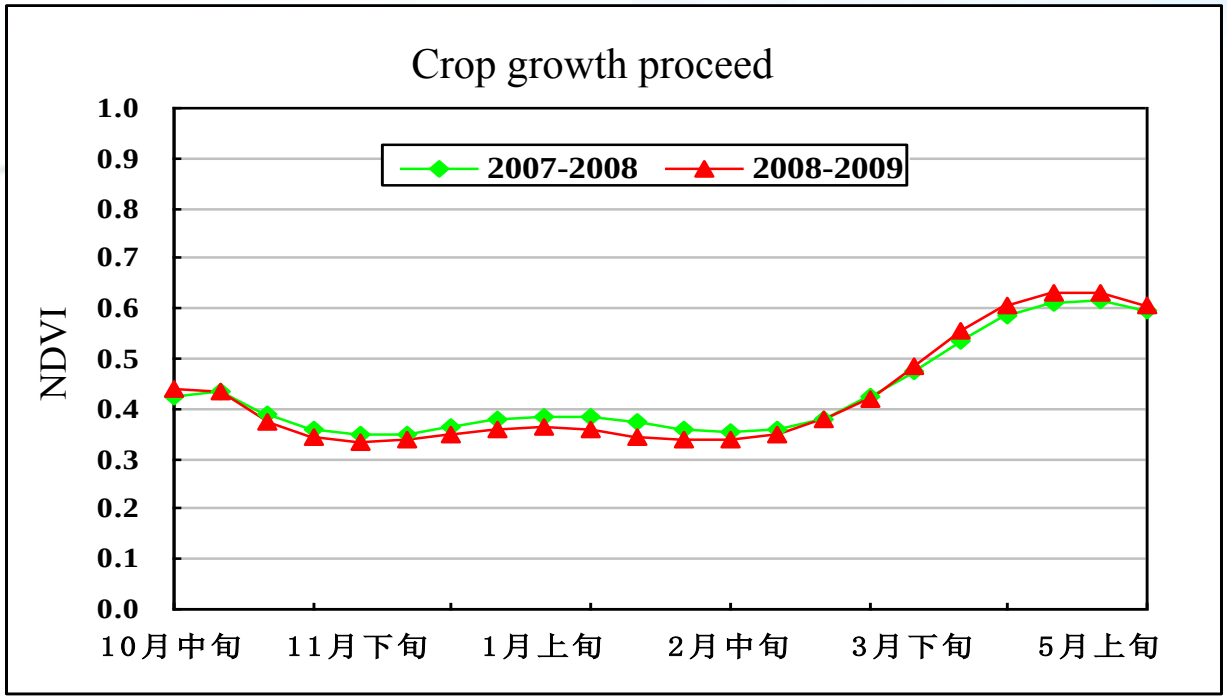


February 1st-10

February 11-16

February17-22

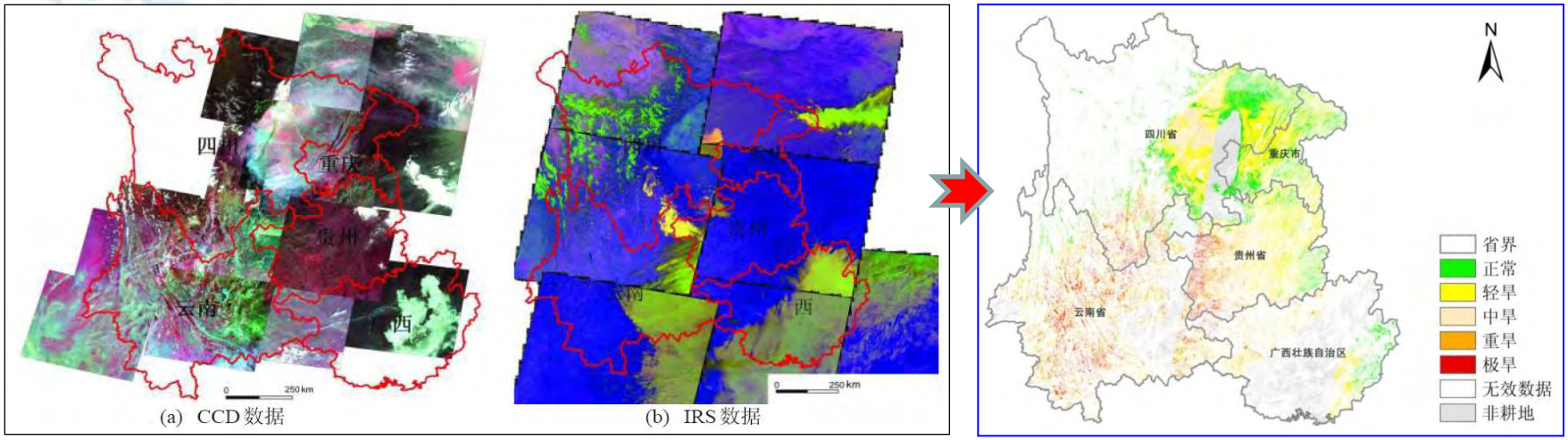
- Because consecutive days without rain and snow reached more than 80 days in the north plain, the area percentage of wheat drought between January 20 and February 16 were 49.5%, 36.9% and 30.5%, respectively.
- Since February 16, the drought area had a large decrease because of precipitation and irrigation in large area of the north plain.



- from November 2008 to February 2009, drought had being affected winter wheat growth.
- the crop conditions in these areas were worse than last year(above graph).

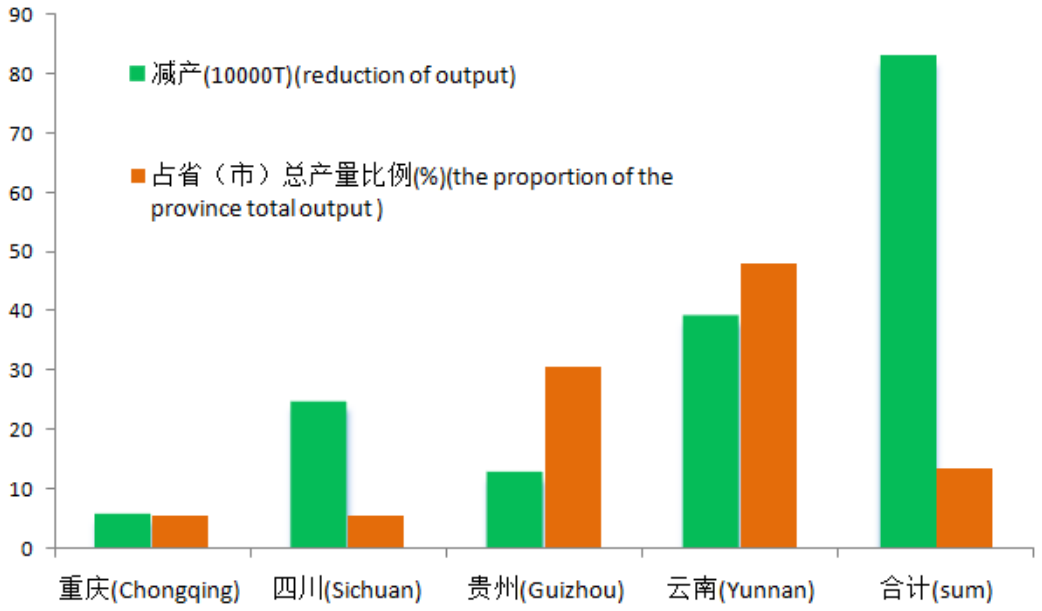
Applications

The Drought Monitoring of the Southwest of China, 2010



- Domestic HJ satellite data(27 scenes) From March 12 to 19, 2010, were used to monitor the regional drought in the southwest of China.
- The result showed that drought in southwest occurred mainly in the central and west of Guangxi, the northeast and southwest of Chongqing, Yunnan, Guizhou, and the central and south of Sichuan.

The Influence of drought on Crop Yield of Winter Wheat



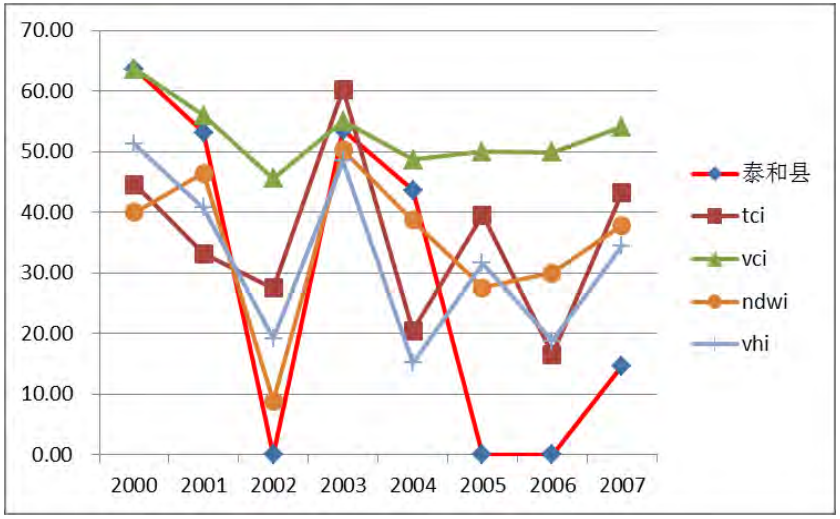
- The winter wheat yield loss was estimated with about 830,000 tons, accounting for about 13.7% of total output of winter wheat of four provinces in 2009, and 0.8% of total output of China;
- There is little impact on the total grain output of China but great impact on regional food supply.

Drought Monitoring-NDWI

- NDWI is very effective to monitoring drought of rice paddy in humid region.

$$NDWI = \frac{\rho_{SWIR} - \rho_{NIR}}{\rho_{SWIR} + \rho_{NIR}}$$

SWIR is the shortwave infrared band and NIR near infrared band, $\rho(\lambda)$ is the reflectivity of λ wavelength.



Taihe County	PRO*	VCI	TCI	VHI	NDWI
PRO*	1				
VCI	0.74	1			
TCI	0.44	0.57	1		
VHI	0.66	0.88	0.86	1	
NDWI	0.83	0.66	0.49	0.63	1

Due to the cropland of growing rice, NDWI is more relevant with the drought statistical data in county, compared with the other drought index(TCI/VCI /VHI) .

Drought Results in Jiangxi Province of China

Jun, 2000	Jul, 2000	Aug, 2000	Sep, 2000
			
Jun, 2003	**Jul, 2003**	**Aug, 2003**	**Sep, 2003**
			

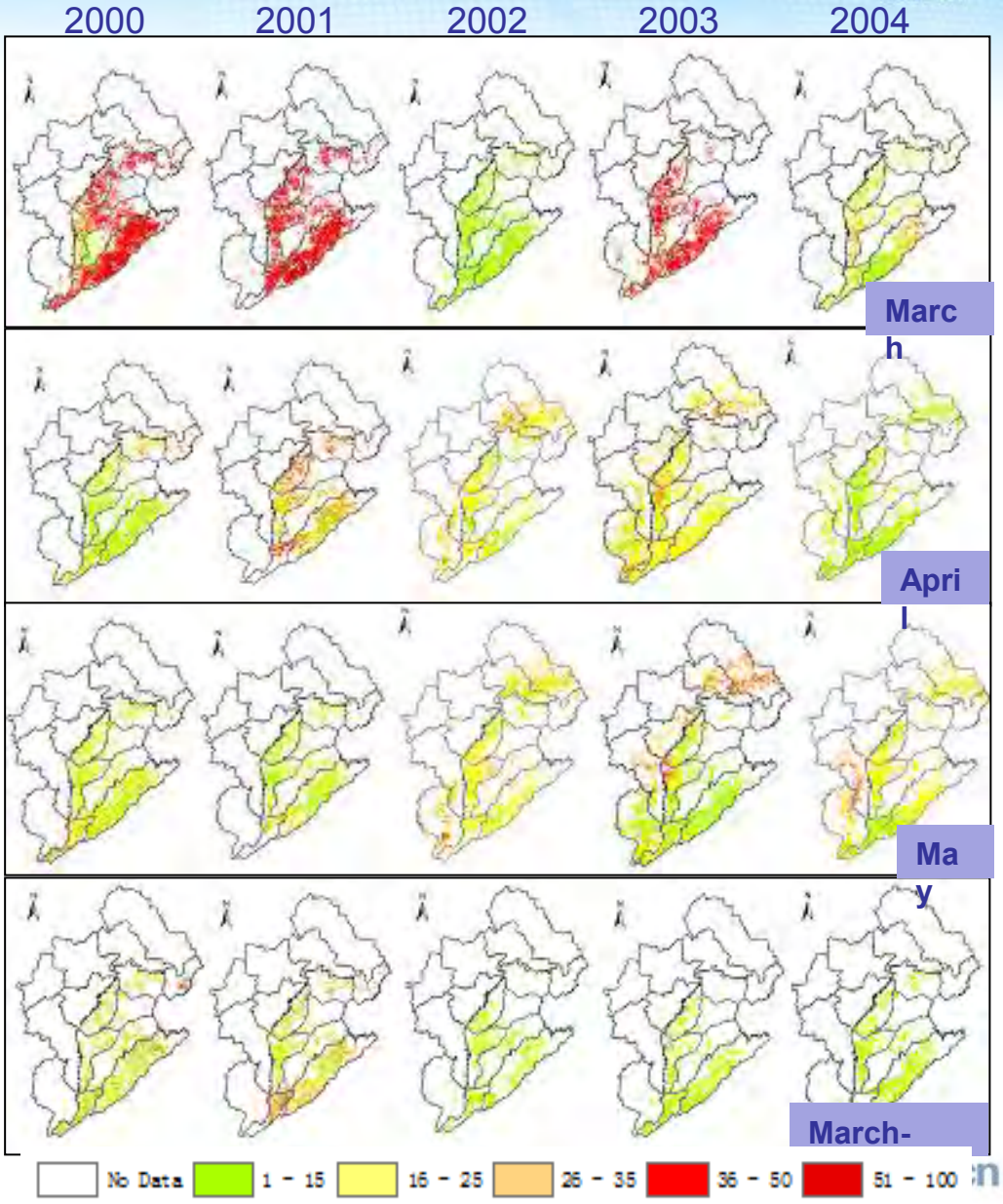
Drought Monitoring-ESI

- Evaportranspiration Stress Index(ESI) is very effective to monitoring drought in Semi humid area.

$$ESI_j = \frac{(PET_j - ET_j)}{\mathrm{PET_j}} * 100$$

- PET is the water requirement of crop; ET is crop evaportranspiration;
- ET is calculated by ETWatch Model, which provide the series of ET data at different durations (ten-days, month and annual);
- PET is the maximum ET of all data set (ten-days, month) .

- The crop growth of winter wheat were affected by serious drought in 2000 and 2001.
- The results are accordant with the statistical drought information.



Outline

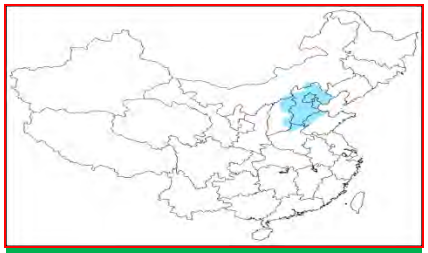
Global

Data:
- TRMM
- AMSR-E
- MODIS

Methodology:
- SPI /VHI
- SM anomaly
- VI anomaly

Temporal and spatial resolution:
- Monthly
- 25km

China

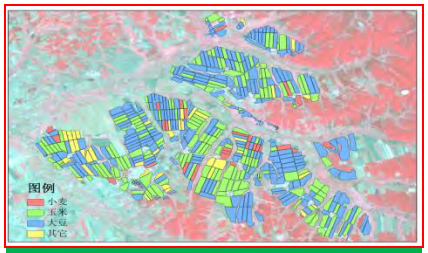


Data:
- MODIS 1B
- FY-3/MERSI

Methodology:
- VCI/TCI/VHI
- ESI/TANDVI
- SM anomaly

Temporal and spatial resolution:
- Ten-day
- 1km

Field



Data:
- HJ-1A/B CCD
- HJ-1 IRS
- TM/SPOT

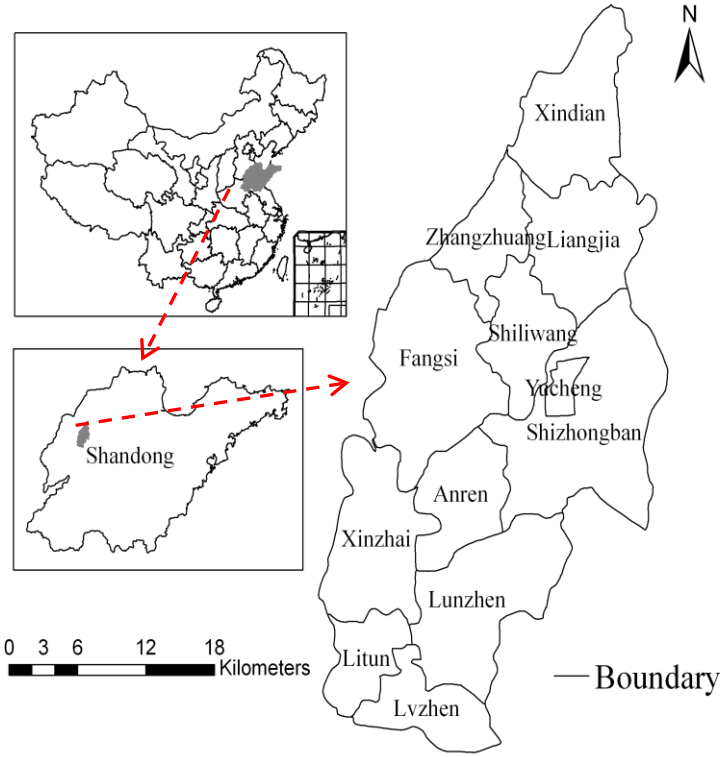
Methodology:
- NDWI
- ESI

Temporal and spatial resolution:
- variable
- 30m/10m

Field Drought Monitoring

Yucheng Farmland

Yucheng is a typical region of North China Plain where winter wheat and summer corn are widely planted.



Data:

HJ-1A/B CCD

HJ-1 IRS

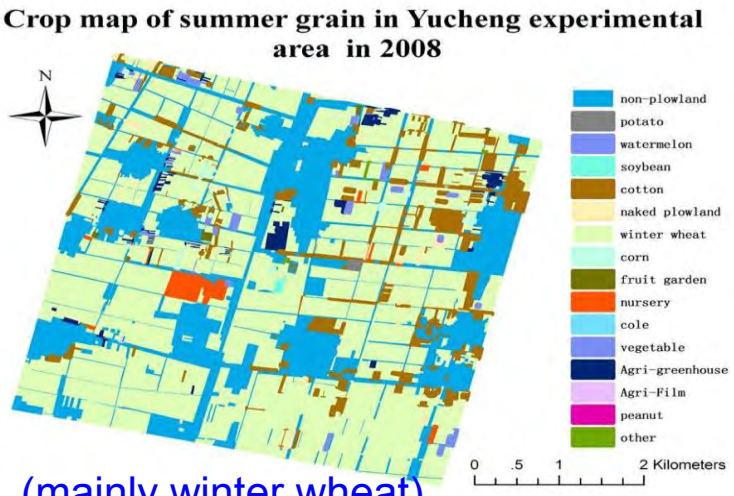
Method:

$$NDWI = \frac{\rho_{SWIR} - \rho_{NIR}}{\rho_{SWIR} + \rho_{NIR}}$$

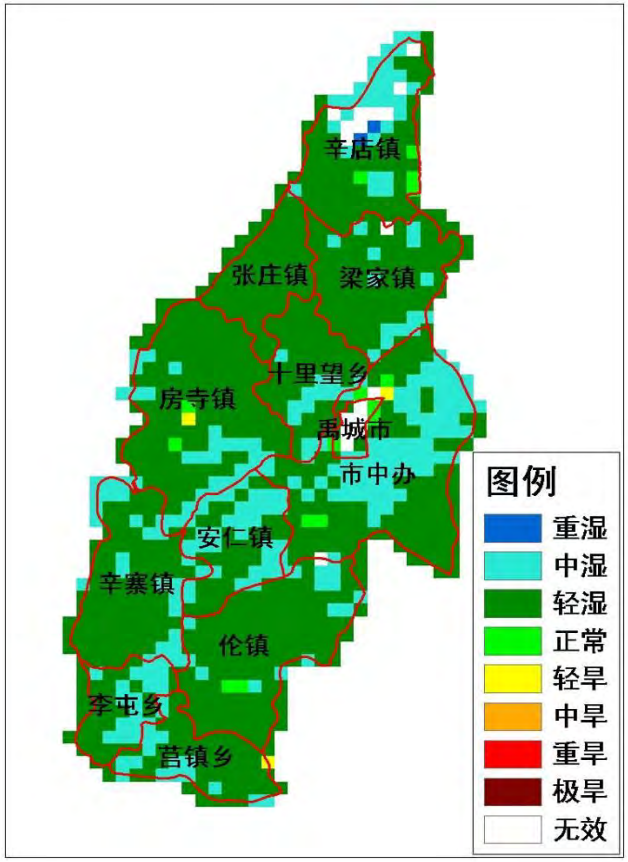
SWIR is the shortwave infrared band and NIR near infrared band.

Drought Monitoring Results

- In late June of 2009, Yucheng region had happened drought with about 1% of the whole arable land.
- In space, drought distributed a few areas, and in the part of North, central and south of Yucheng was wet.



(mainly winter wheat)

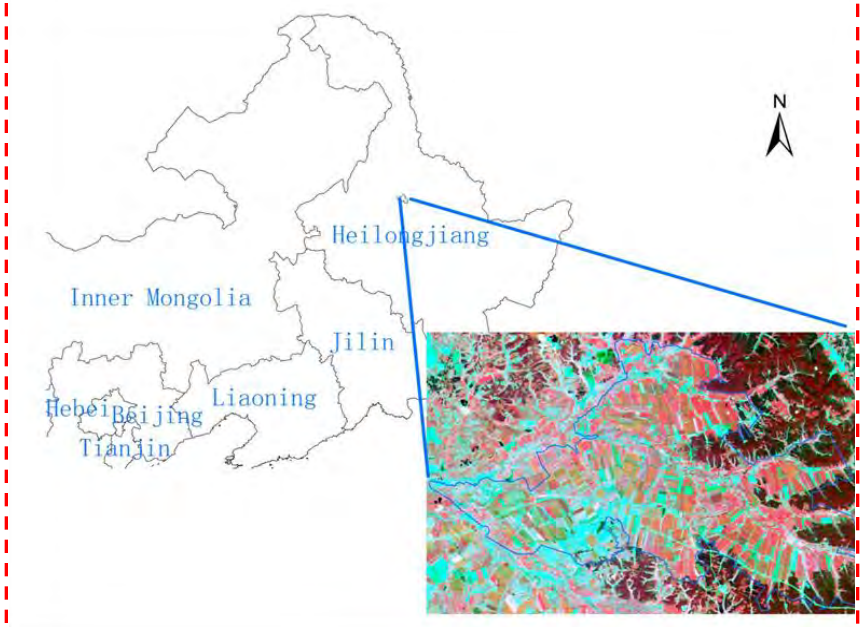


Drought results of Yucheng in late June of 2009

Field Drought Monitoring

Hongxing Farm

Hongxing Farm locates in the north of Heilongjiang province, northeast of China. Crops there are dominated by soybean, spring corn and spring wheat.



Data:

HJ-1A/B CCD and IRS of 26th,August 2010

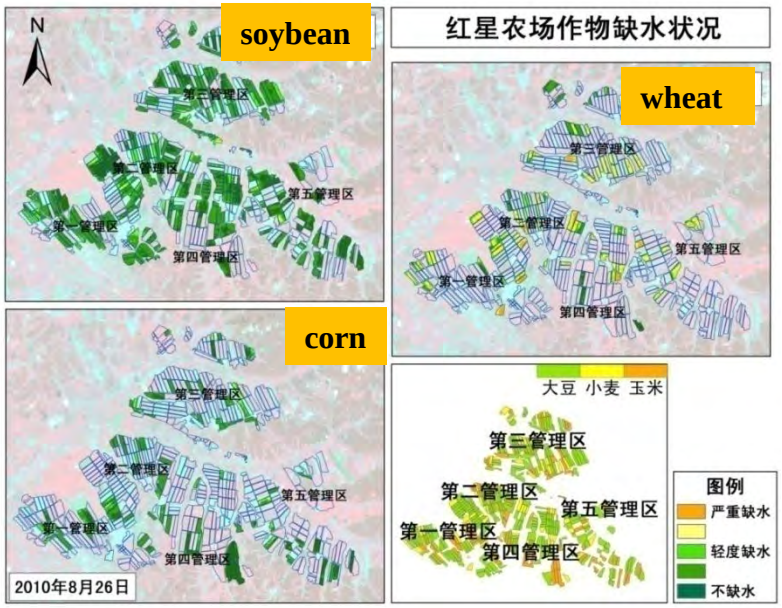
Method:

$$NDWI = \frac{\rho_{SWIR} - \rho_{NIR}}{\rho_{SWIR} + \rho_{NIR}}$$

SWIR is the shortwave infrared band and NIR near infrared band.

Drought Monitoring Results

- The crop growth of farmland in August 2010 suffered water deficit lightly, most of which was no lack of water and light water scare.
- Most soybean and corn was in no lack of water situation.
- Wheat area was light water scare, which is relation to the crop phenology.



Prospects

- **Further Application of Earth Observation**
  - New data source, especially the high resolution satellite , such as HJ, need be applied for regional monitoring and disaster loss estimation.
  - Combination of optical and microwave data would provide the reliable and new information on drought monitoring
- **New indices combining the meteorological model, agricultural model & hydrological model**
  - Soil Moisture is not a good indicator for all crop season, new indicator should be studied, such as crop evaportranspiration stress index.
  - Scale effect analysis of indices from different models
  - Composite indices would be studied adapting to the regional characteristics.
- **Further study on drought prediction and risk management**

Thanks!






Institute of Remote Sensing and Digital Earth
Chinese Academy of Sciences
Add：No.9 Dengzhuang South Road,Haidian District,Beijing 100094,China
Tel：86-10-82178008 Fax：86-10-82178009
E-mail：office@radi.ac.cn
Web：www.radi.cas.cn