Introduction of FengYun-3/MWRI soil moisture product and its applications

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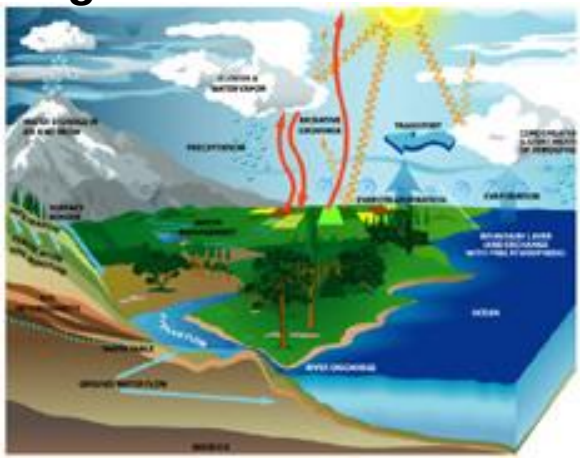
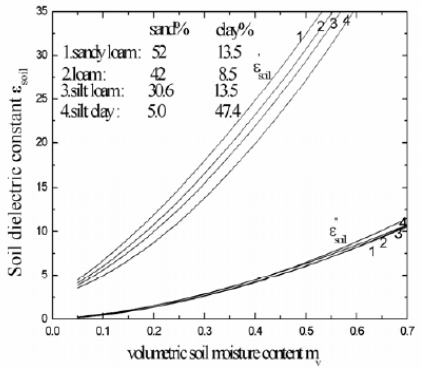
outline

1. Introduction of passive microwave remote sensing of soil moisture
2. FY3D/MWRI soil moisture product: algorithm and validation
3. Development of fused soil moisture
4. Applications

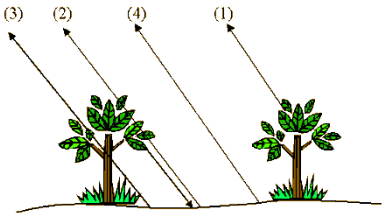
1. Introduction of passive microwave remote sensing of soil moisture



- Soil moisture is a key parameter in the global energy and water cycle. Global soil moisture observations were prove to be very useful in meteorology, climatology, hydrology and agriculture.
- **The microwave remote sensing**
  - ➢ Less affected by cloud and weather conditions
  - ➢ Sensitive to the dielectric constant of soil



Roughness



Vegetation

Terrain

- ➢ Active: higher spatial resolution, relatively lower sensitivity to soil moisture(more sensitive to surface roughness and vegetation).
- ➢ Passive: higher sensitivity to soil moisture, multi-bands, lower spatial resolution, .

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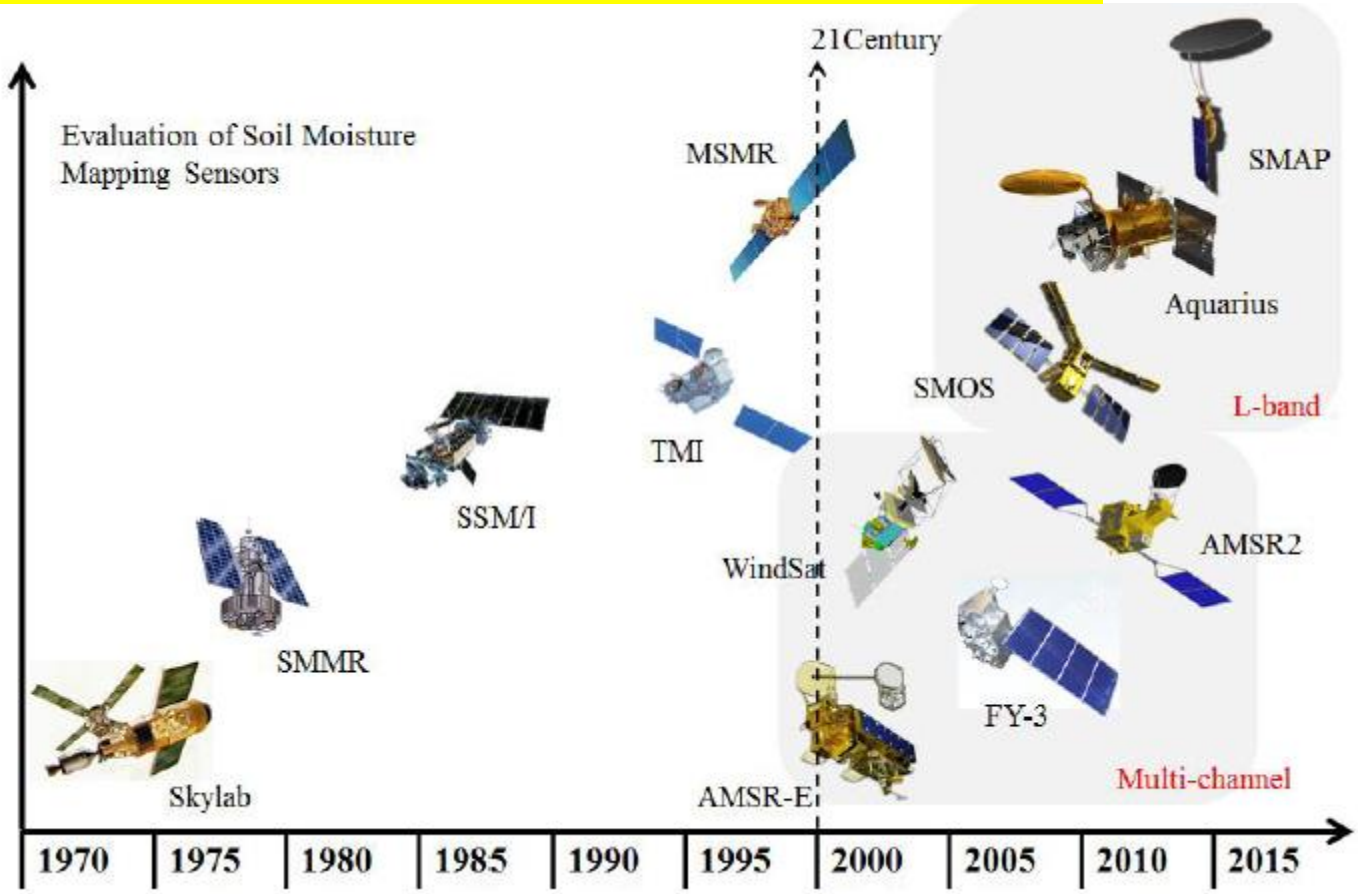
1. Introduction of passive microwave remote sensing of soil moisture

➢ Development of spaceborne microwave radiometers



➢AMSR-E on EOS-Aqua: 2002.5.4 – 2011.10.4

➢AMSR2 on GCOM-W1： 2012.5-

➢SMOS: 2009.11.2 –

➢SMAP： 2015.1-

➢**MicroWave Radiation Imager** on FY-3:

FY3B： 2010.11–2019.8

FY3C： 2013.9–2020.2

FY3D： 2017.11–

2. FY-3/MWRI soil moisture product: algorithm and validation

FY-3/MWRI (MicroWave Radiation Imager)

- MWRI is a highly sensitive microwave radiometer. It has 5 different frequencies from 10.65GHz to 89GHz with both V and H polarization. The MWRI instrument provides measurements of terrestrial, oceanic, and atmospheric parameters, including precipitation rate, sea ice concentration, snow water equivalent, soil moisture, atmospheric cloud water, and water vapor.
- Spatial resolution: 25km

Instrument configurations of MWRI

frequency(GHz)	10.65	18.7	23.8	36.5	89
polarization	V.H	V.H	V.H	V.H	V.H
bandwidth(MHz)	180	200	400	900	2×2300
sensitivity(k)	0.5	0.5	0.8	0.5	1.0
Calibration accuracy(k)	1.0	2.0	2.0	2.0	2.0
Dynamic range(k)	3 ~ 340				
Sampling points	240				
Scan pattern	conical				
swath(Km)	1400				
Antenna angle(°)	45±0.1				

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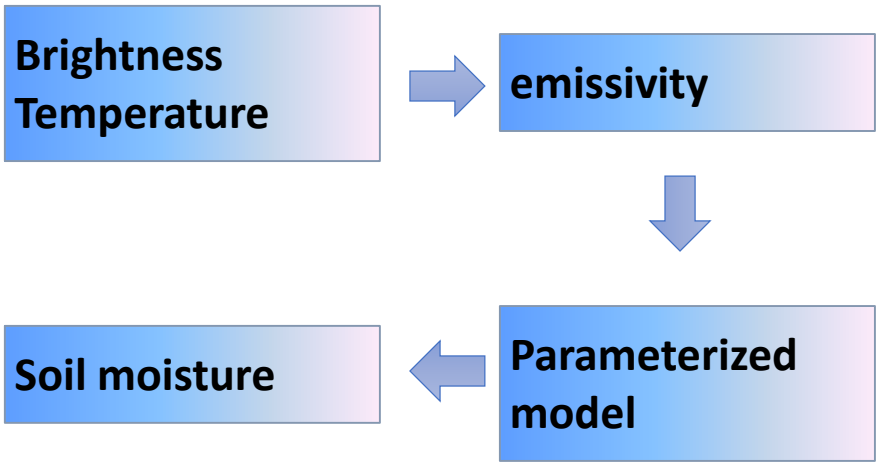
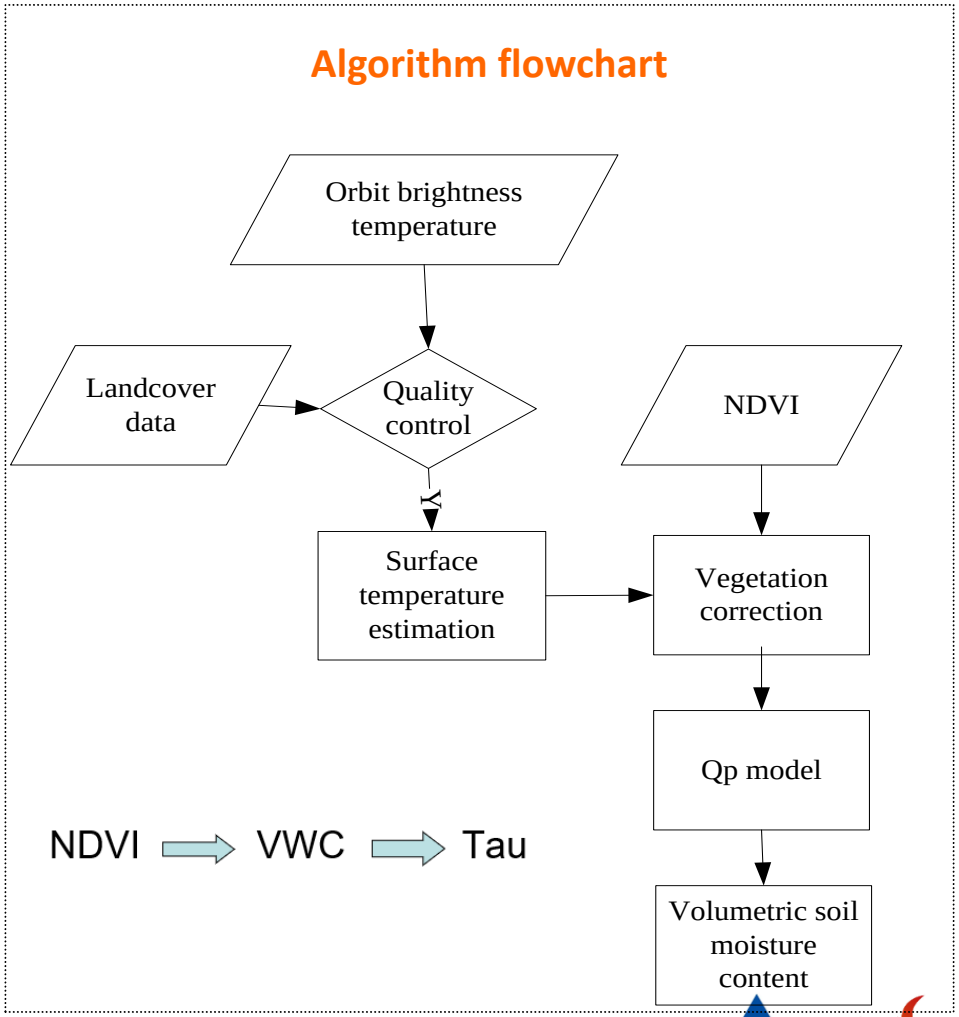
2. FY-3/MWRI soil moisture product: algorithm and validation

Retrieval principal

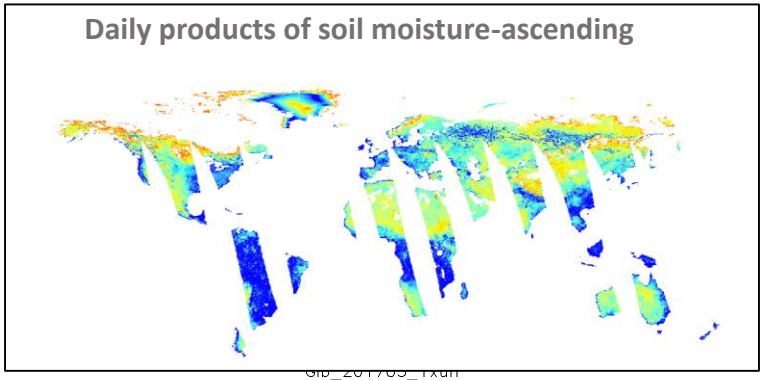


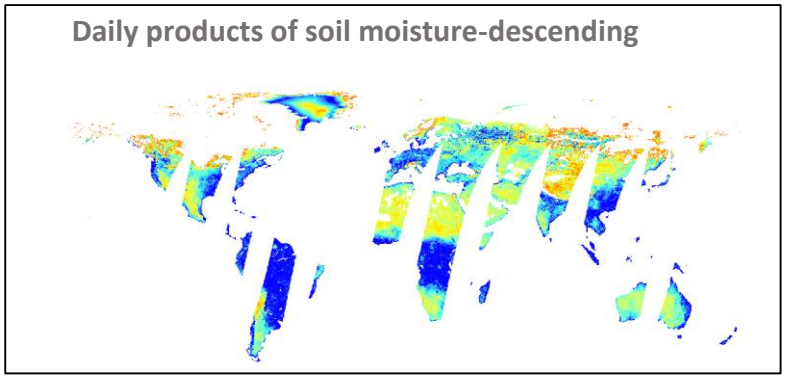
Soil moisture retrieval based on microwave remote sensing is generally using the physical model or semi-empirical model which describing the relationship among surface emissivity, soil moisture and vegetation water content. Through these models, the soil moisture content is derived.

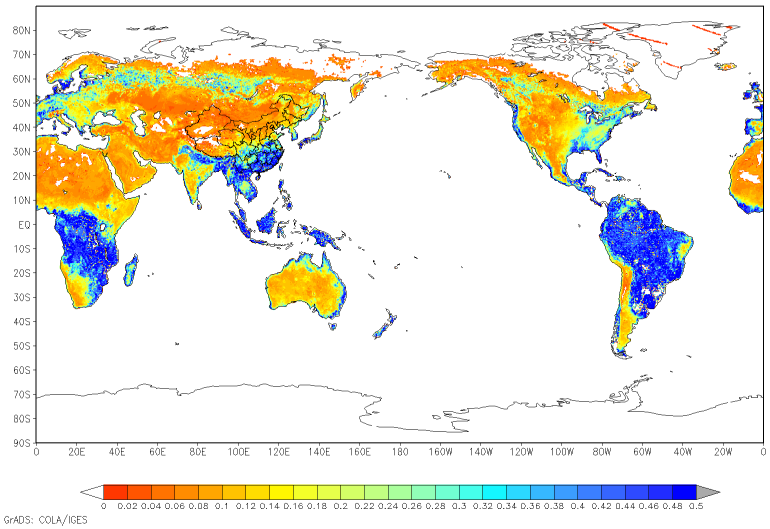
Algorithm flowchart

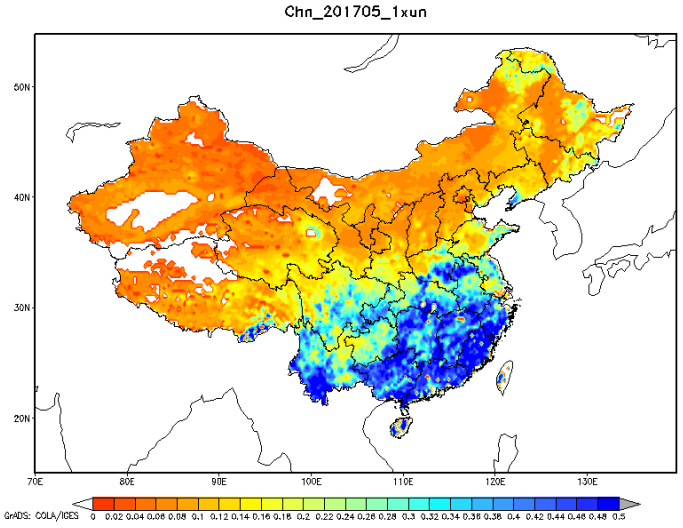


2. FY-3/MWRI soil moisture product: algorithm and validation









- The MWRI instrument has a fixed scanning swath, therefore there maybe gaps between adjacent orbits especially in low latitude areas. So we also provide the L3 products which include 10-day composed products and monthly averaged products.

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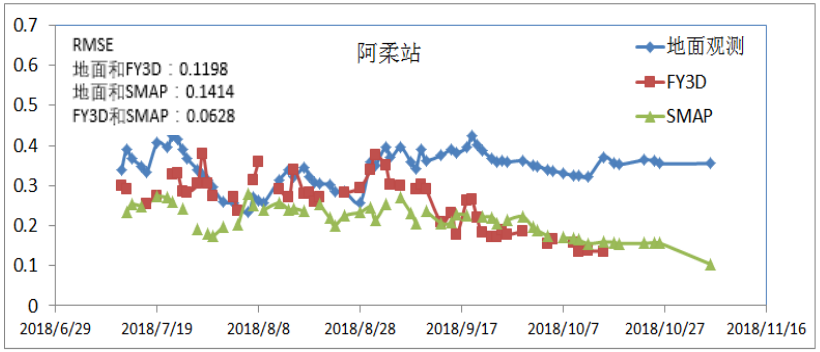
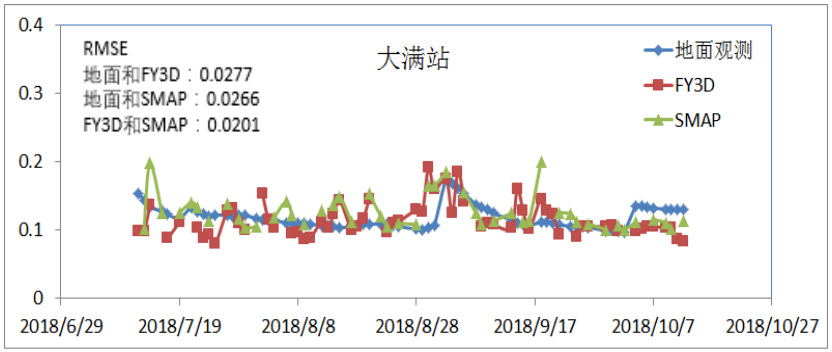
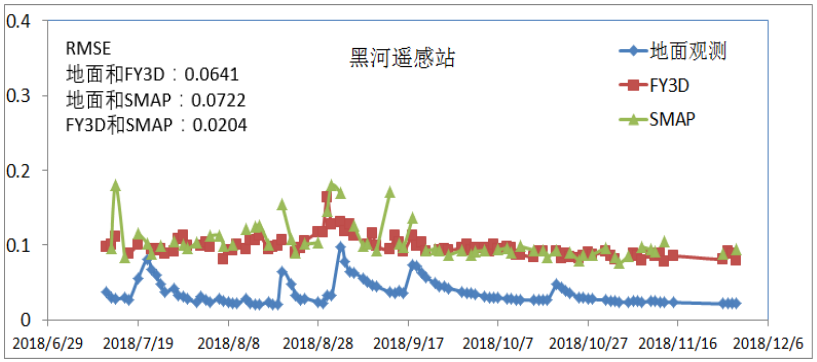
2. FY-3/MWRI soil moisture product: algorithm and validation

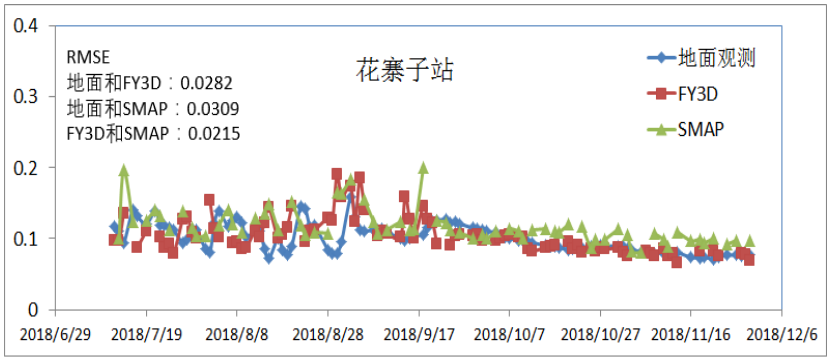
Validation dataset:

- SMAP L3 product (L3_SM_P)
- Soil moisture ground observation (Dataset of the Heihe River Basin integrated observatory network)









3. Development of fused soil moisture

Why we need to development the fused soil moisture using multi-sensors?

- **Advantage：** High time resolution; Data accumulation for more than ten years.
- **Disadvantage：** Low spatial resolution; Bands limitation and algorithm limitation.

Solution：

Retrieval of fused soil moisture by multi-source microwave sensors

-- Retrieval technique fusion(machine learning)

-- Product fusion(MWRI/AMSR2/SMAP)

Fusion target:

Higher precision **Higher resolution**

More information **Timeliness**

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3. Development of fused soil moisture

FY-3 soil moisture retrieval algorithm based on machine learning

The object variable: SMAP (Soil Moisture Active Passive)

Advantage: 1) Better penetration ability(L-band) 2) Higher precision

The selection of characteristic variables	
Brightness Temperature of X to W-band	FY-3/MWRI 5 bands，V/H polarization
Quasi-emissivity of X band	$Tb_{10GHz\_V/H}/Tb_{36GHz\_V}$
Microwave vegetation index	$(Tb_{18GHz\_V}-Tb_{18GHz\_H})/(Tb_{10GHz\_V}-Tb_{10GHz\_H})$
Band ratio(Scattering characteristics)	$Tb_{36GHz\_V/H}/Tb_{18GHz\_V/H}$
Band ratio(Water vapor effect)	$Tb_{23GHz\_V/H}/Tb_{18GHz\_V/H}$

The training process:

(1) Randomly selected global data between FY-3D and SMAP in the year of 2019

(2) Using random forest model, 70% data were used for training and 30% for validation

(3) Optimize model parameters

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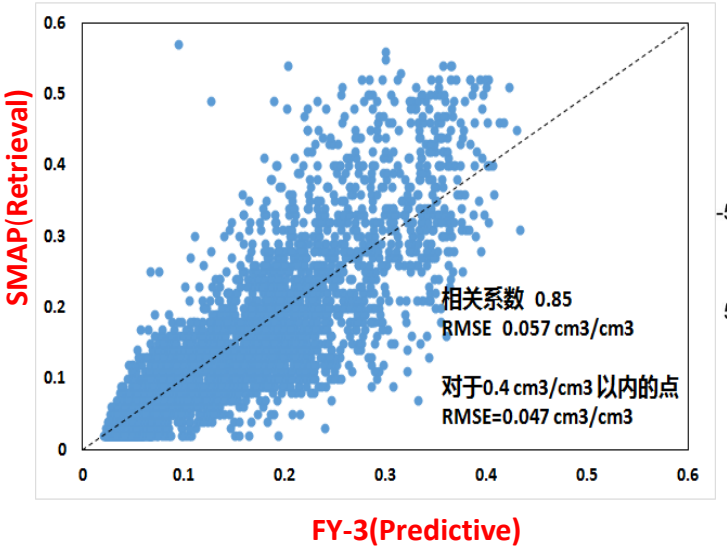
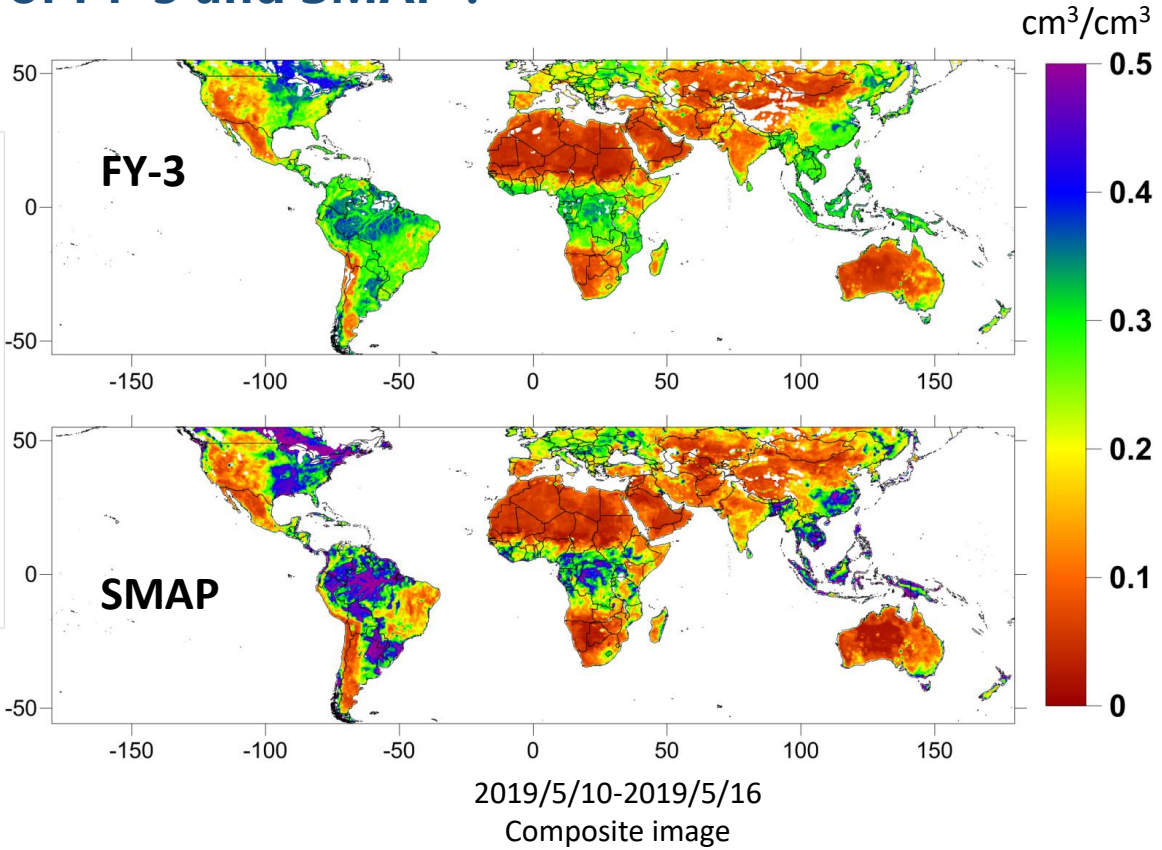
3. Development of fused soil moisture

Quantitative comparison of FY-3 and SMAP：



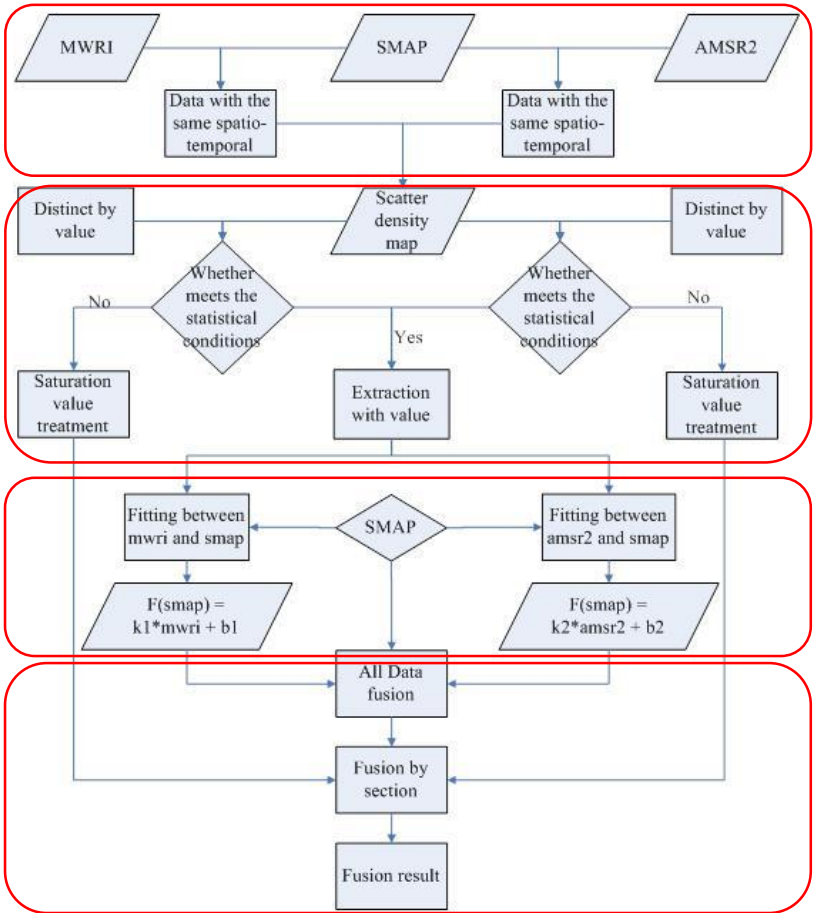


- **Verification shows:**
  - **(1) The spatial distribution of predicted FY-3 soil moisture is similar to SMAP.**
  - **(2) Better correlation in medium-low vegetation cover area.**

3. Development of fused soil moisture

Product fusion:

Sensor	Frequency (GHz)	Spatial Resolution (km)	Observation
MWRI	10.65	25	13:00/1:00
AMSR2	6.9/7.3/10.65	10	13:30/1:30
SMAP	1.41	36	6:00/18:00



(1) Extract soil moisture content according to observation time and area of multi-source satellites

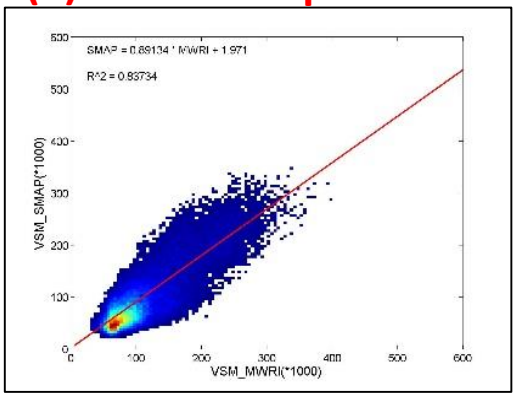
(2) Make density maps and eliminate outliers

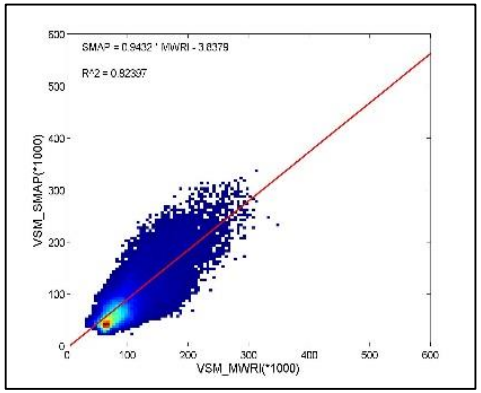
(3) Find the relationship and fitting function

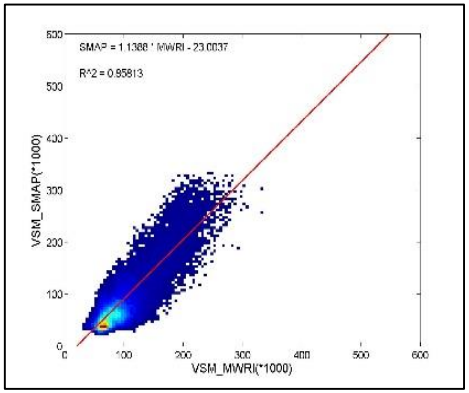
(4) Results Fusion

3. Development of fused soil moisture

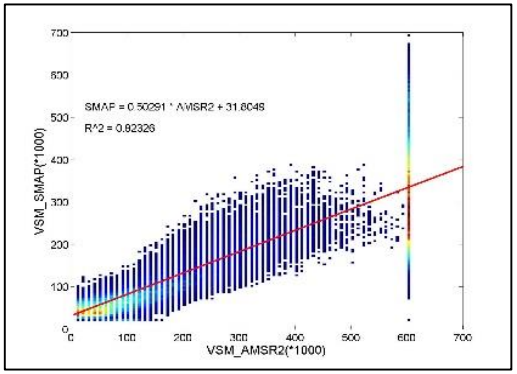
(1) Scatter maps between SMAP and FY-3

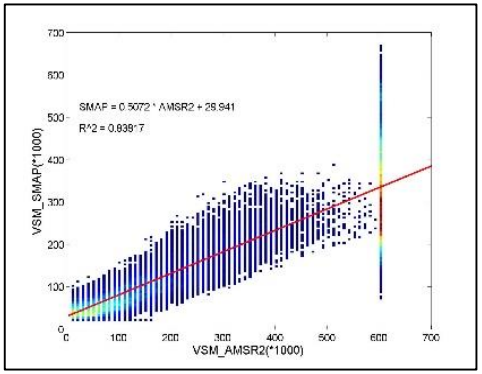


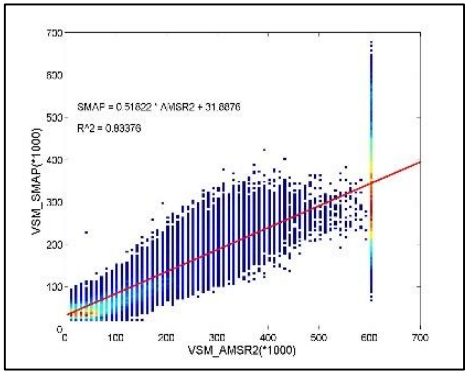




(2) Scatter maps between SMAP and AMSR2



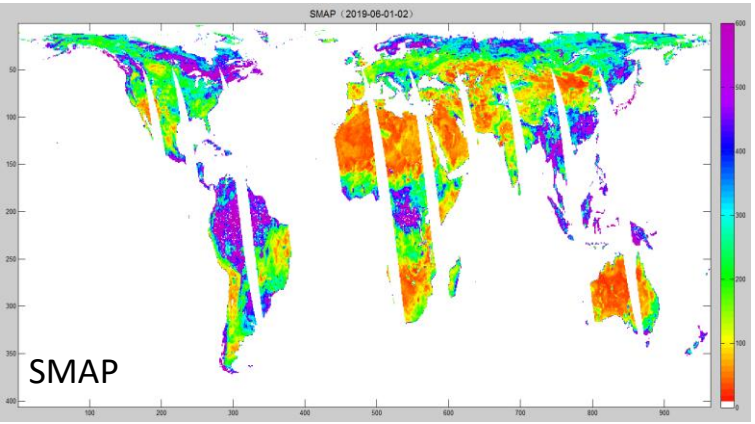


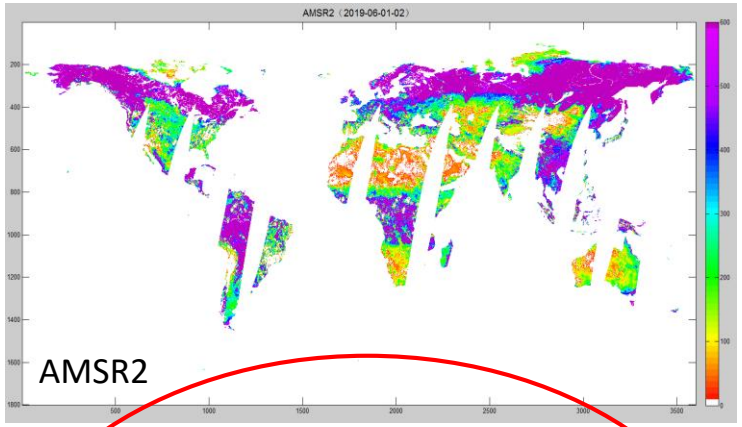


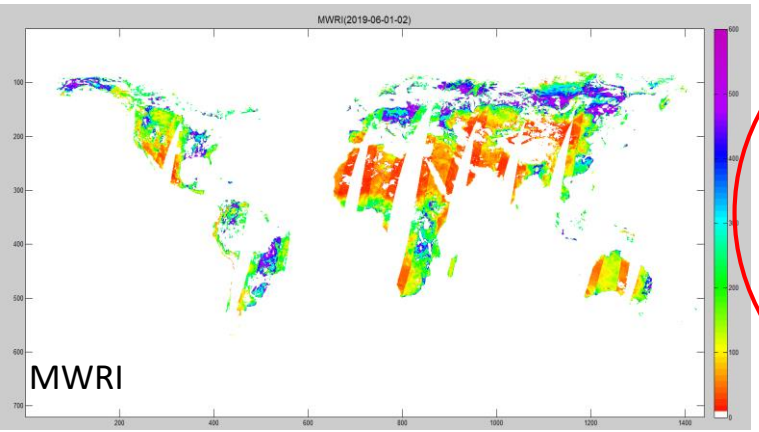
	K1	K0	R
SMAP_MWRI	0.87	7.23	0.81
	0.91	2.86	0.79
	1.00	-5.77	0.82
SMAP_AMSR2	0.52	28.55	0.84
	0.52	27.67	0.86
	0.55	27.20	0.85

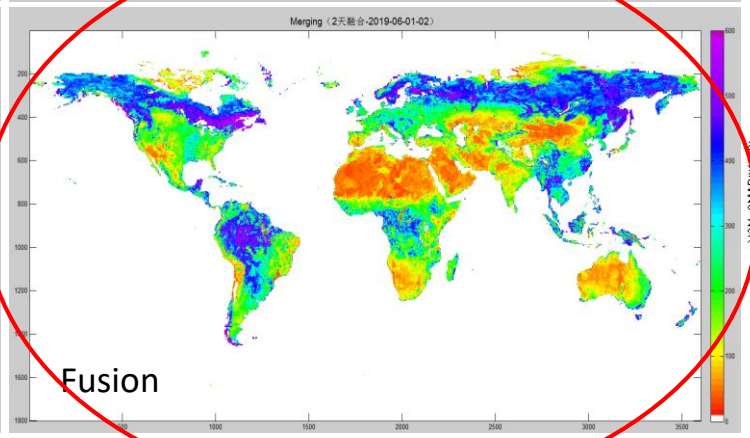
SMAP = k1 * (MWRI or AMSR2) + k0

3. Development of fused soil moisture

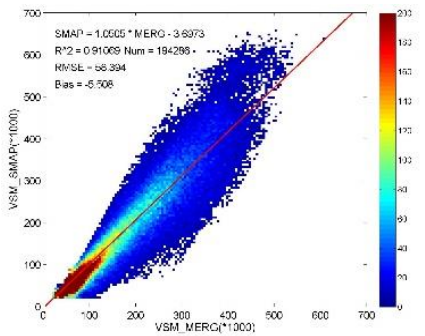


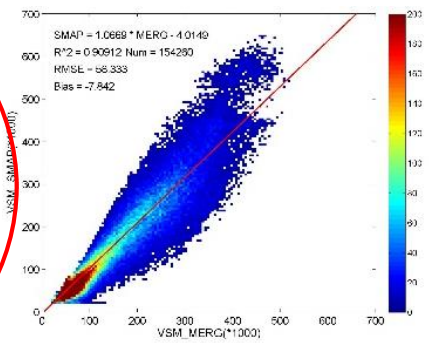






2019/6/1-2019/6/2





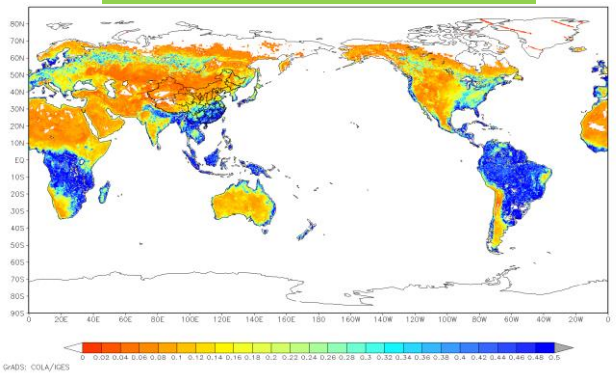
Validation of fused soil moisture

- The fused soil moisture can achieve a wider coverage with a resolution of 10km.
- The average RMSE between fused soil moisture and SMAP is less than 0.055 cm^3/cm^3.
- The accuracy varies in different seasons.

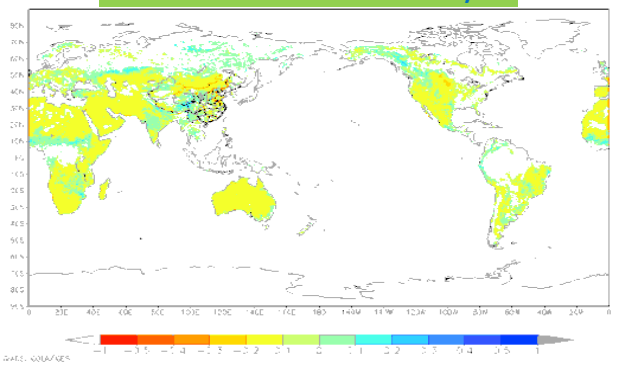
4. Applications——Drought monitoring

- Drought is one of the major natural disasters globally. In recent years, drought occurs more frequently even in those areas which barely have drought before. Consequently drought related parameters such as soil moisture become closely concerned.

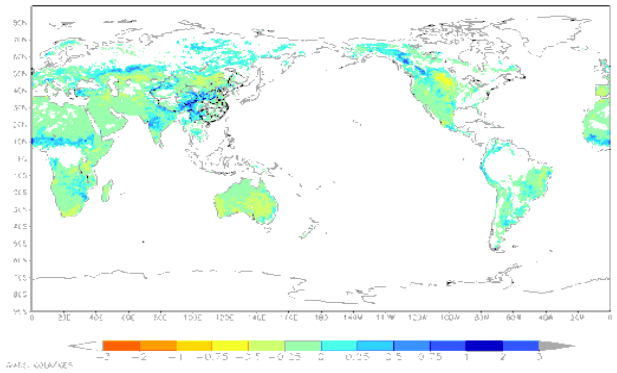
Soil moisture content



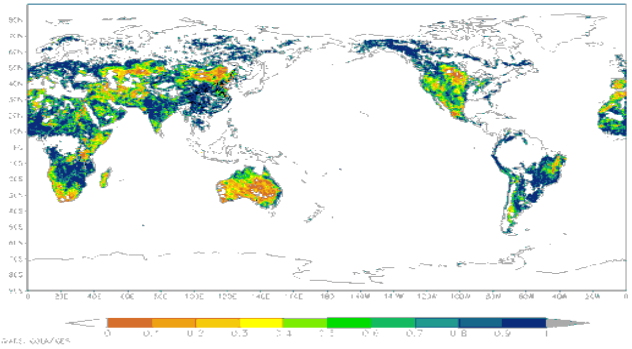
Soil moisture anomaly



Percentage of soil moisture anomalies

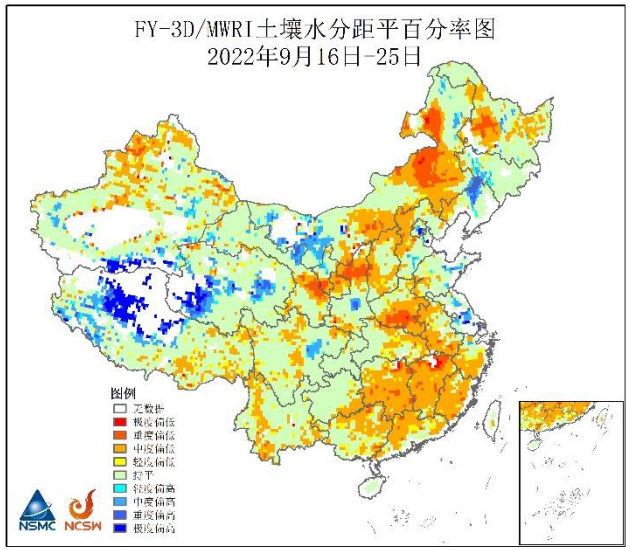


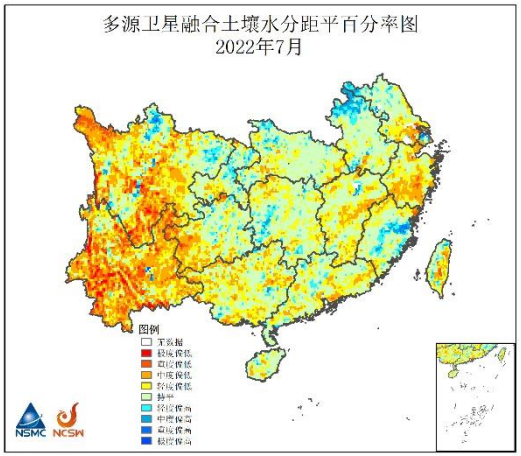
Soil moisture index

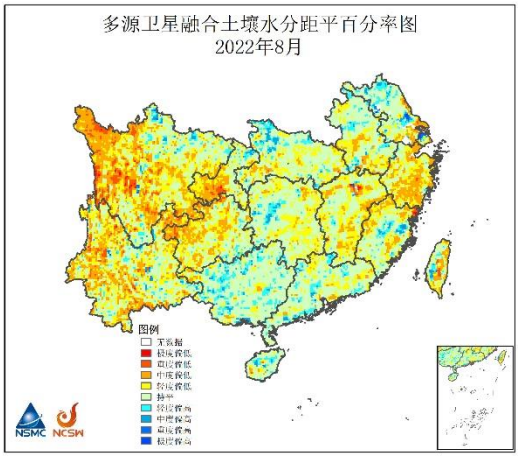


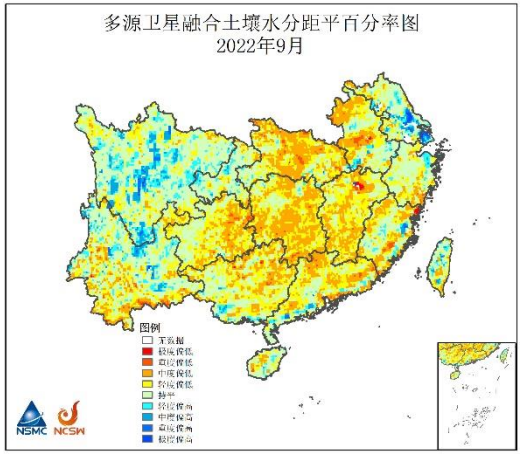
4. Applications——Drought monitoring

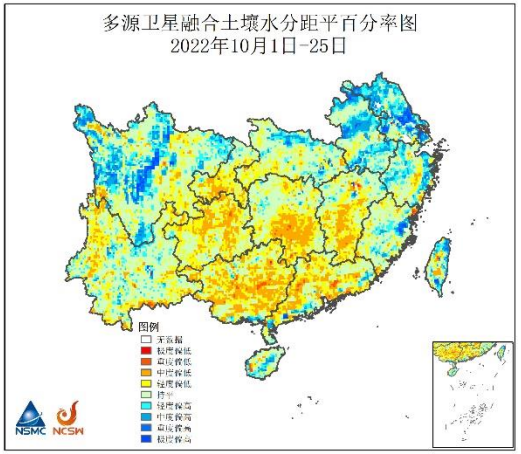
- Recent drought in South China.











- These images showed that the soil moisture anomaly decreased significantly in recent months.

The changes of soil moisture can reflect the whole process of drought, including occurrence, development and mitigation.

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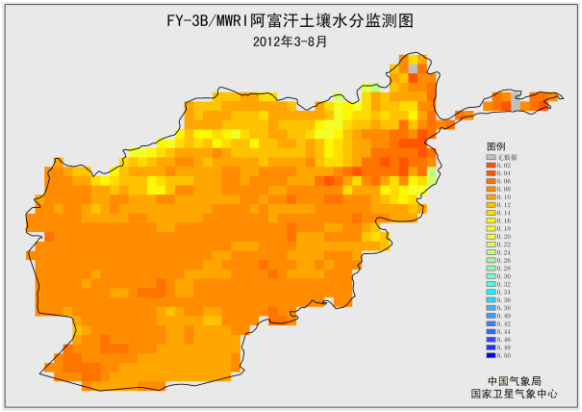
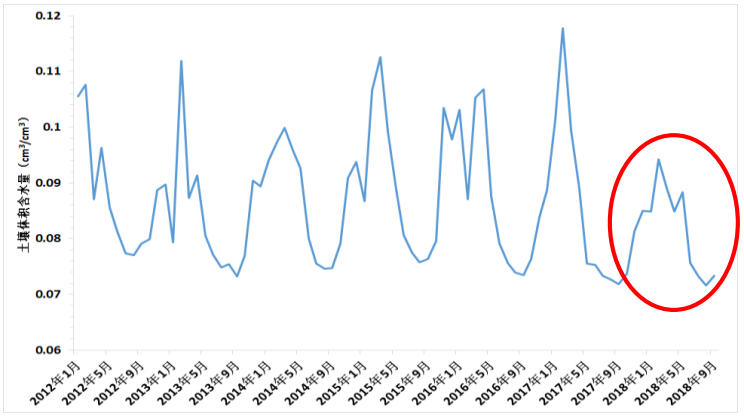
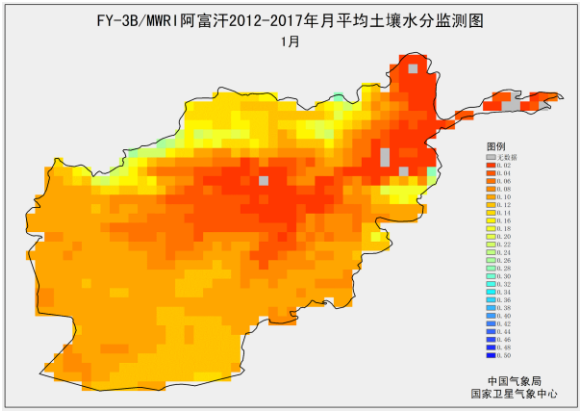
4. Application——Drought monitoring

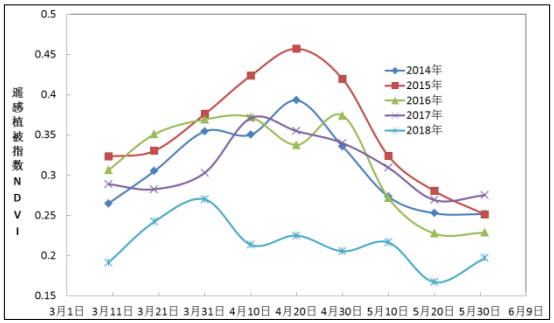
Remote sensing monitoring services for the Belt and Road countries.

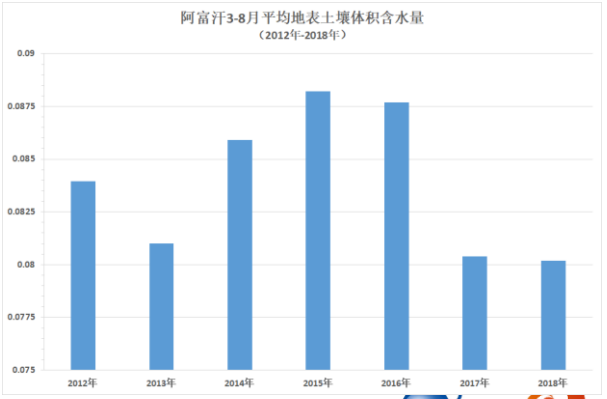
- Drought in Afghanistan in 2018.
  - The soil moisture changes in Afghanistan from 2012 to 2018 demonstrated that the soil moisture was significantly lower in 2018.











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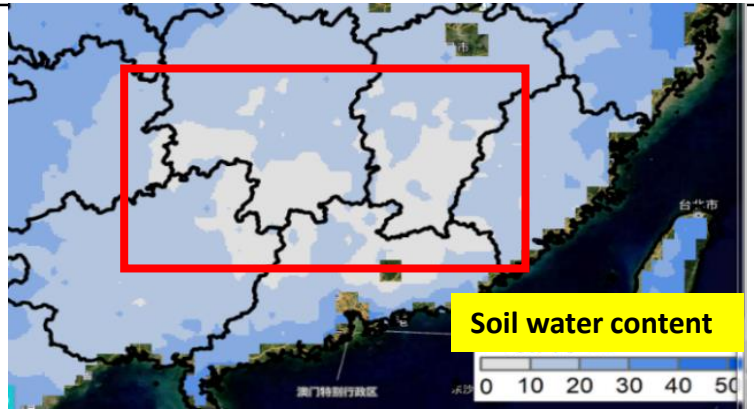
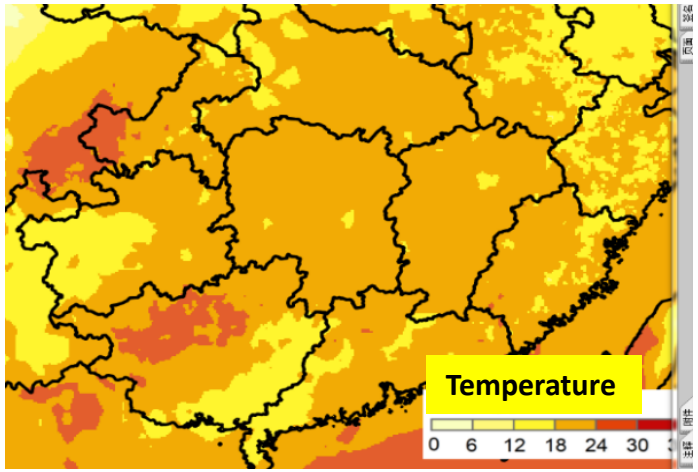
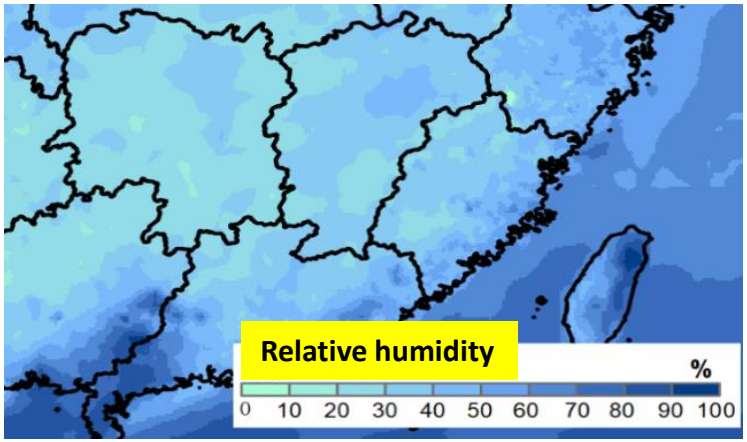
4. Applications——Fire risk

The distribution of fire points highly matches the low value area of soil moisture, but the correlation among fire points with land surface temperature and relative humidity is relatively weak.

Soil moisture was the best indicator of fire risk during this period.







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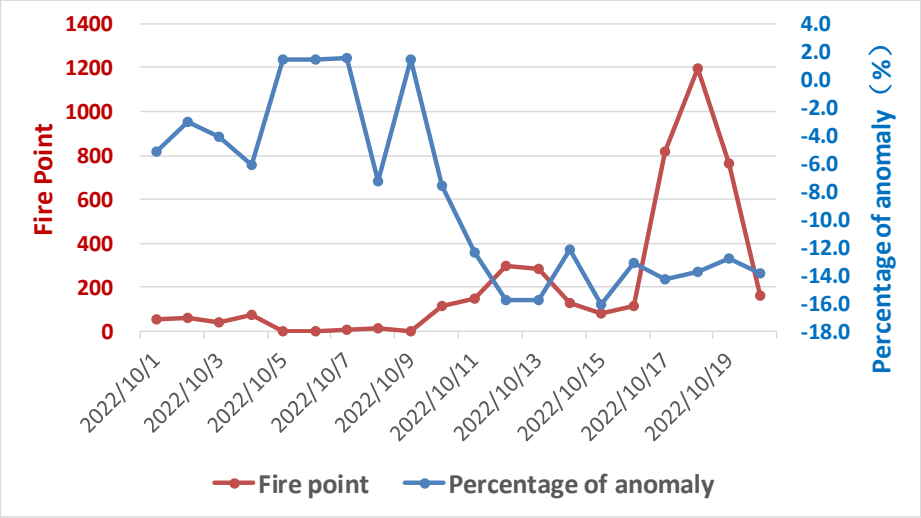
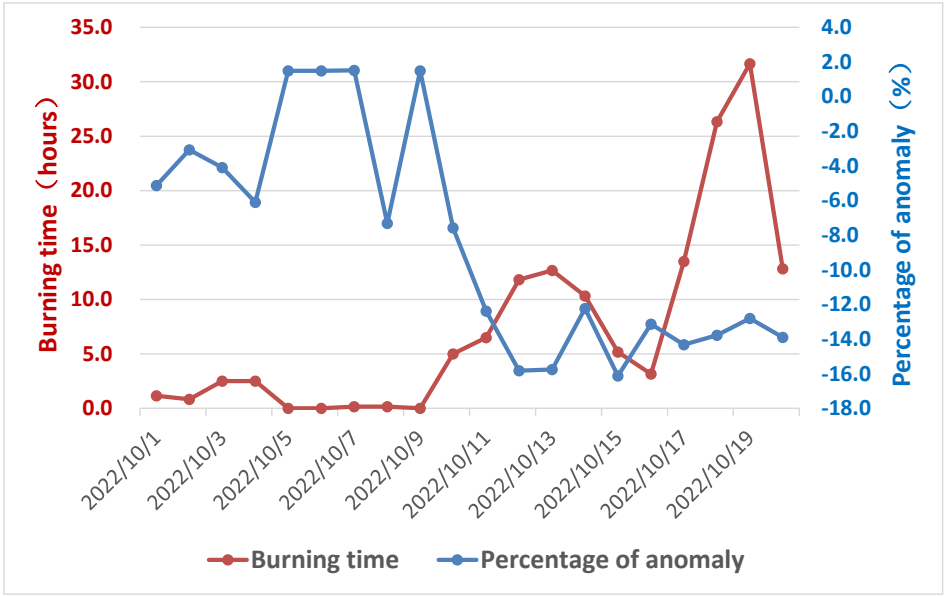
4. Applications——Fire risk

Correlation analysis between the percentage of soil moisture anomalies and fire risk





From October 1 to 20, 2022, the number of fire points and the percentage of soil moisture anomalies (compared with the average of the past 10 years) showed negative correlation. From October 1st to 9th, most water content anomalies were within -6%, and the maximum daily fire in the two regions was less than 100 times. Since October 10, the moisture content had fallen sharply, with more than -16%. From October to 20th, the number of **fire points in this area was negatively correlated with water content**. That is, when the percentage of moisture anomalies is lower than -12% (relatively dry), the number of fire points will increase, as well as the fire risk.

The relationship between burning time and the percentage of soil moisture anomalies is consistent with the number of fire points. When the surface combustibles are relatively dry, the burning time will rise accordingly.

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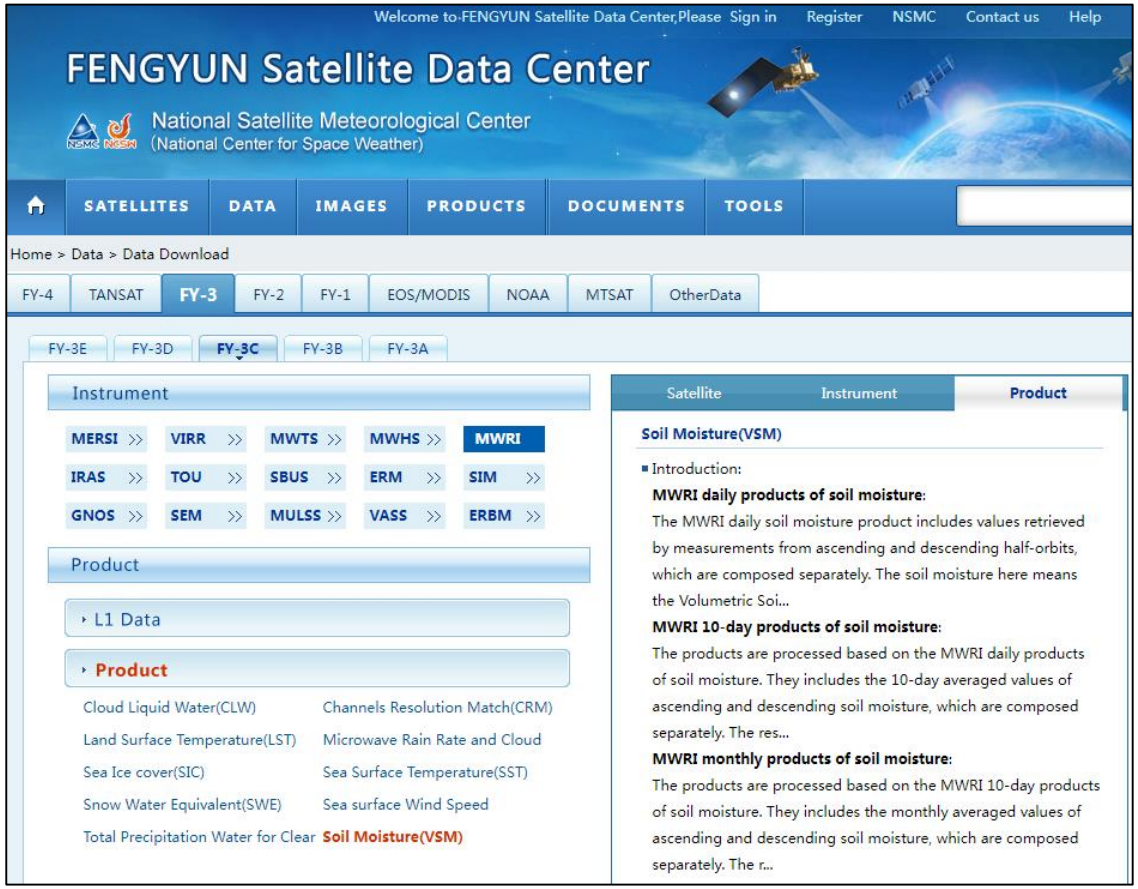
Conclusion

- The FY-3/MWRI soil moisture product is credible.
- FY-3/MWRI data collection is more than 10 years.
- We will have the next FY-3 satellite in the near future.

Data acquisition

FY-3/MWRI soil moisture product download:
http://data.nsmc.org.cn/PortalSite/Data/Satellite.aspx?currentculture=en-US



For fused product: e-mail to sunrj@cma.gov.cn

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Thanks for your Attention!