Institute of Remote Sensing and Digital Earth
Chinese Academy of Sciences

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PERSPECTIVES ON CHINESE DEVELOPMENTS IN SPACEBORNE IMAGING SPECTROSCOPY: WHAT'S NEW IN 2016

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OUTLINE

1. Introduction
2. Onboard Chinese Hyperspectral Missions
3. New Spaceborne Imaging Spectroscopy
4. Upcoming missions
5. Conclusions

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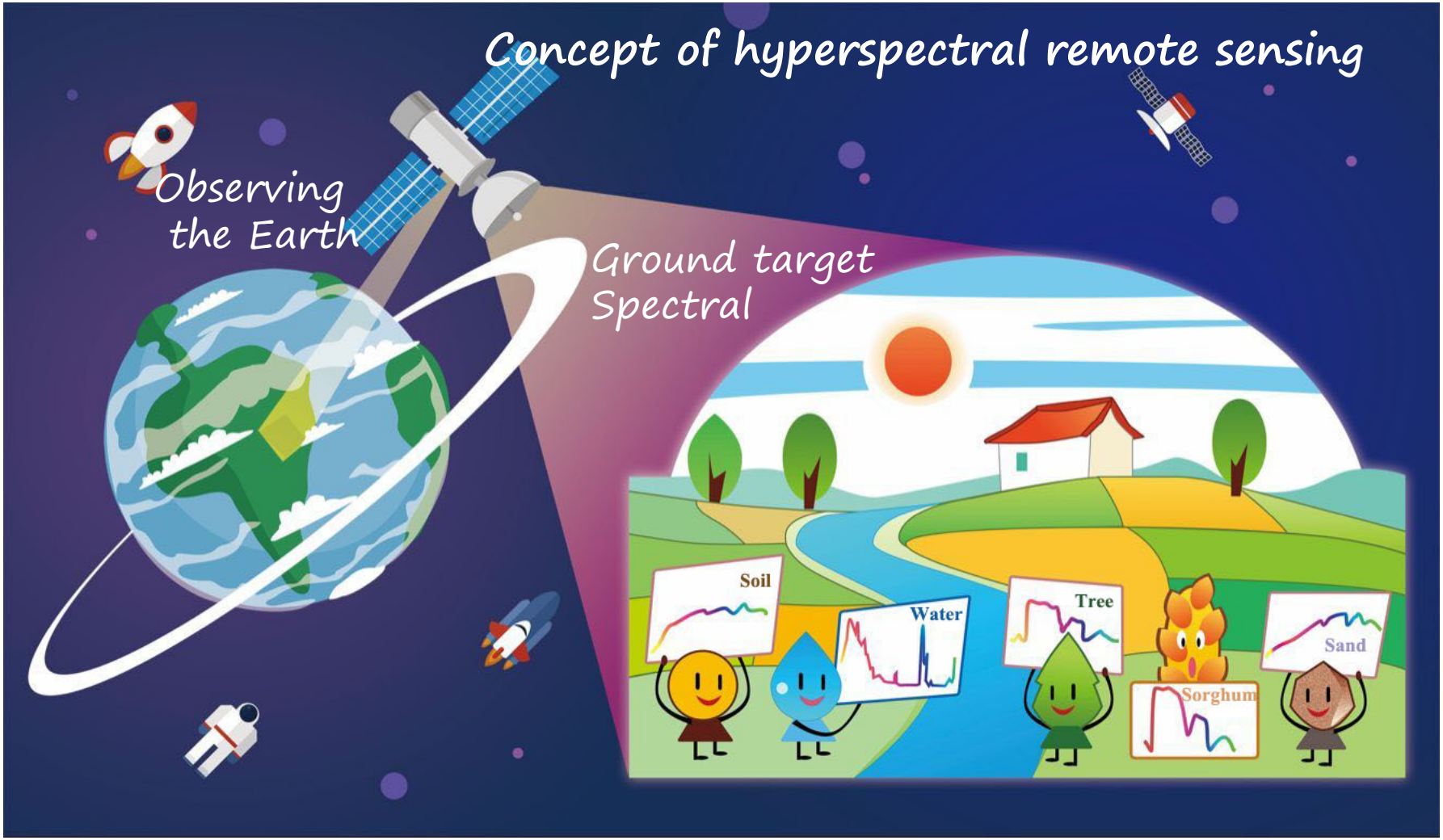
Introduction

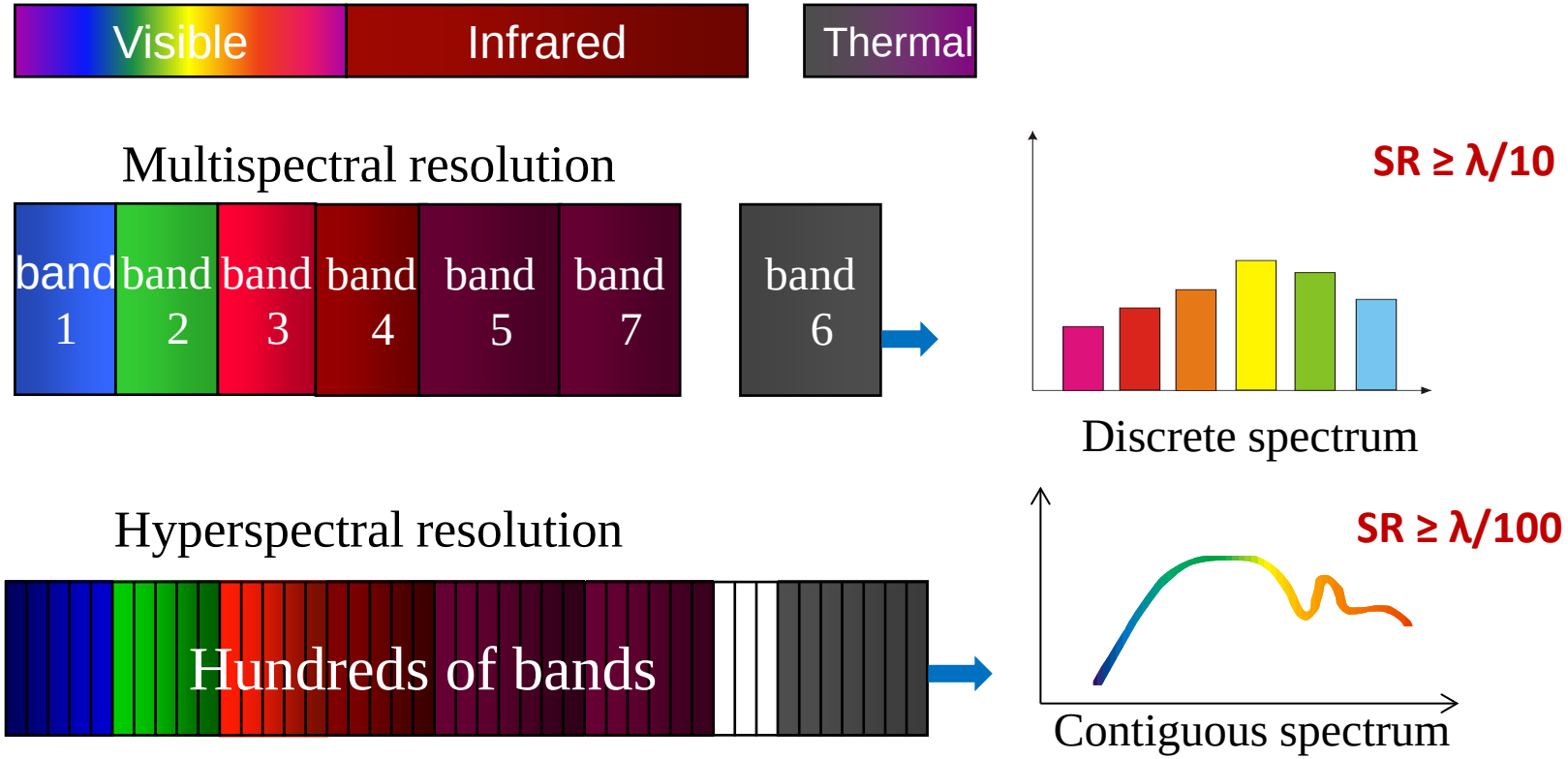
Concept of hyperspectral remote sensing



Introduction

What is hyperspectral remote sensing?

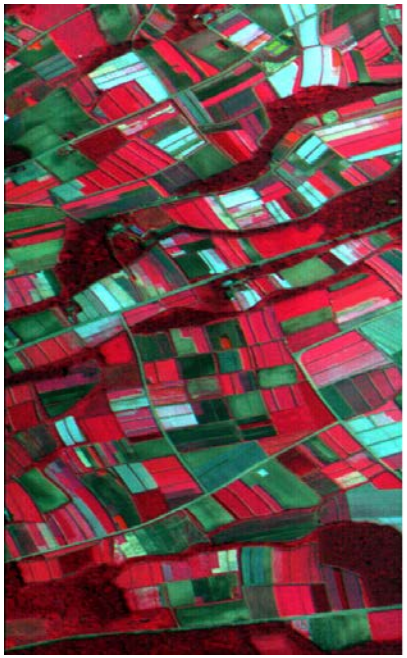
- Spectral Resolution ≥ λ/10 : Multi-spectral
- Spectral Resolution ≥ λ/100 : Hyper-spectral
- Spectral Resolution ≥ λ/1000: Super-spectral



Introduction

Why is hyperspectral remote sensing?(i)

- It offers revolutionized concepts from a spectral perspective which is completely different from traditional spatial domain-based wisdom in remote sensing community.
- It solves many problems that cannot be resolved by multispectral imaging such as subsample and mixed sample issues；

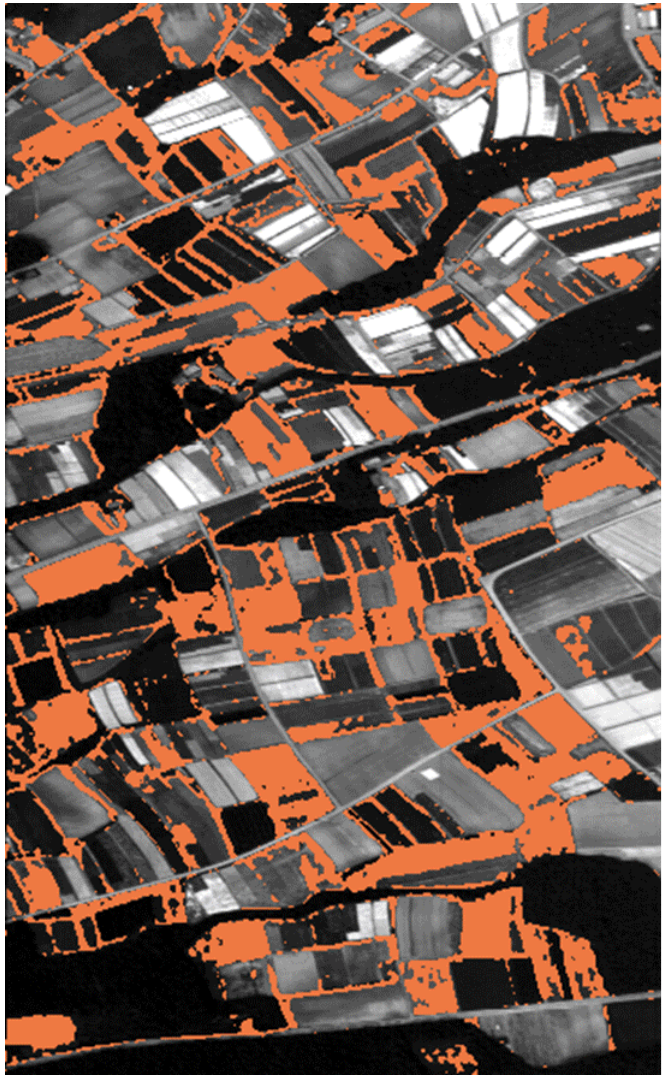


Multispectral imagery

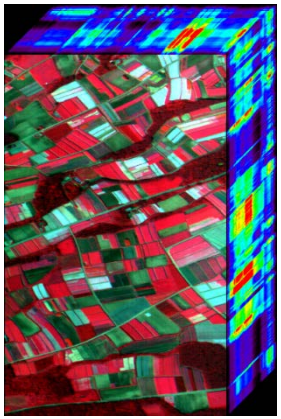
Multispectral data can only classify 4 categories of the objects.

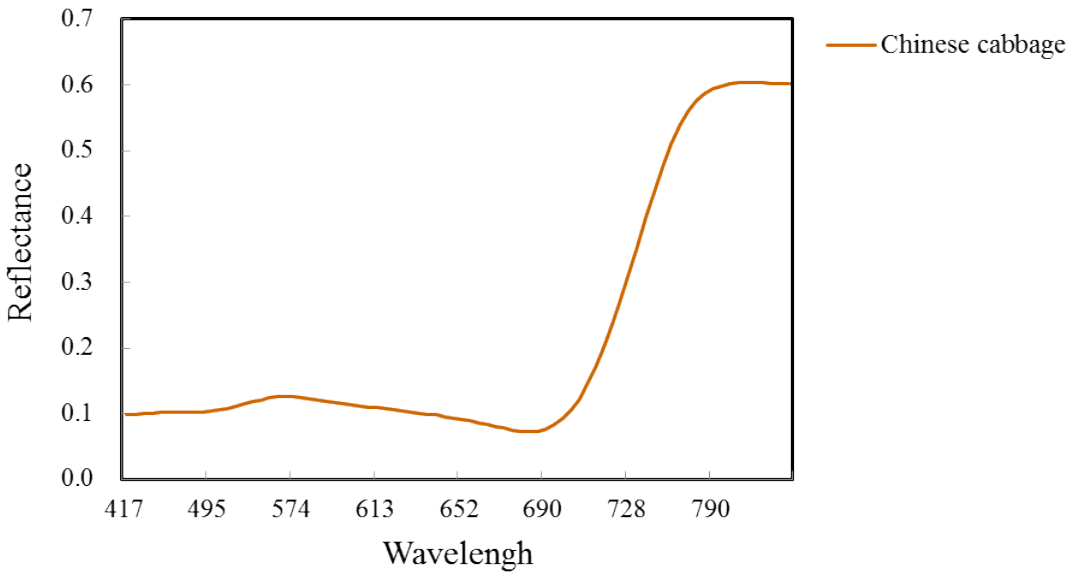
Introduction

Why is hyperspectral remote sensing?(ii)



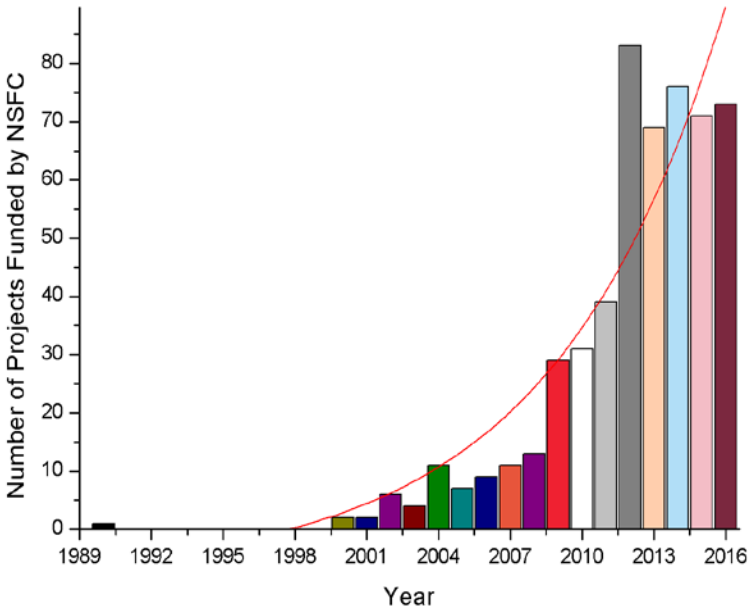
Hyperspectral imagery can classify 10 categories of the objects.



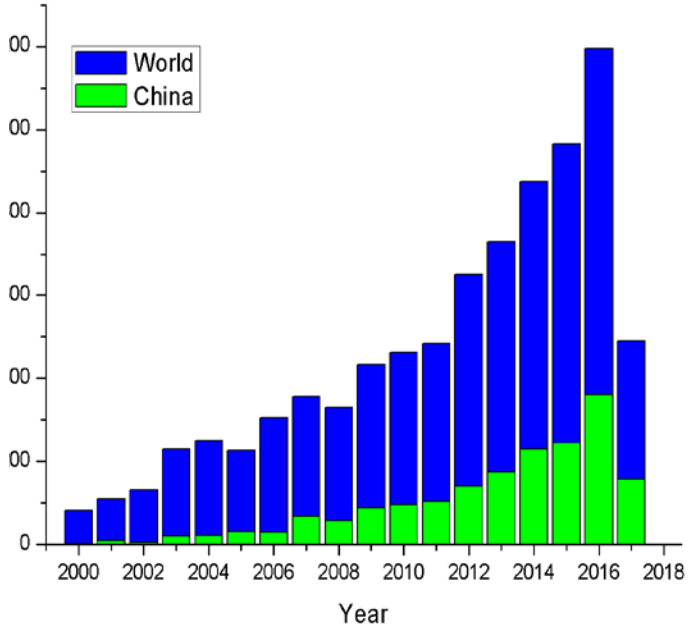


Introduction

Hyperspectral remote sensing a research hot spot



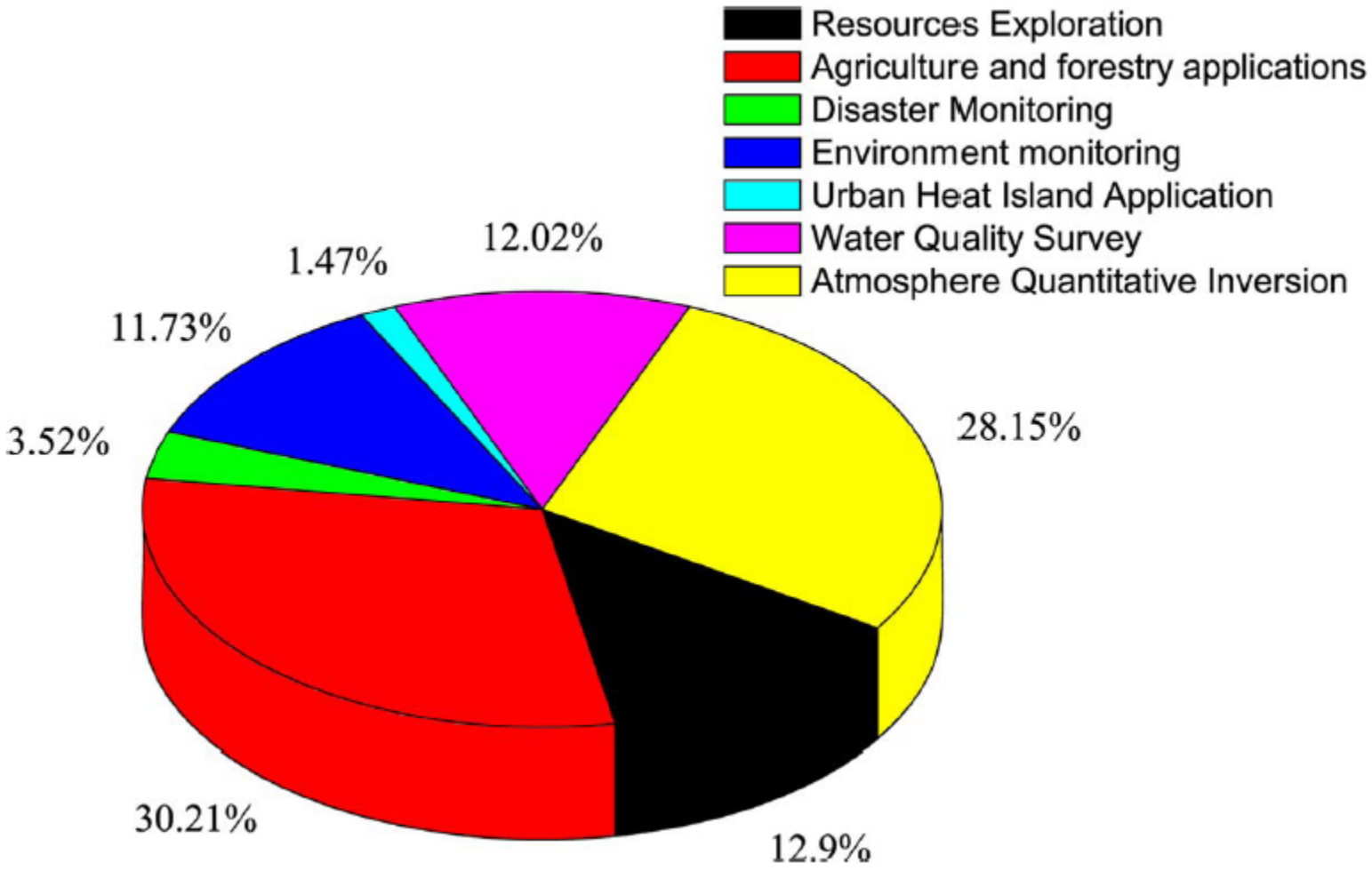
Number of projects supported by the NSFC from 1990 to 2016 (data taken from http://www.nsfc.gov.cn/Portal0/default152.htm).



High-quality papers related to HRS written by Chinese and world wide scientists from 1995 to 2017 (data taken from Web of Science).

Introduction

Who is interested in Hyperspectral remote sensing



Distribution of the main HRS application domains in China

OUTLINE

1. Introduction
2. Onboard Chinese Hyperspectral Missions
3. New Spaceborne Imaging Spectroscopy
4. Upcoming Hyperspectral Missions
5. Conclusions

Onboard Chinese Hyperspectral Missions

Overview

Spaceborne Hyperspectral Imaging Sensor

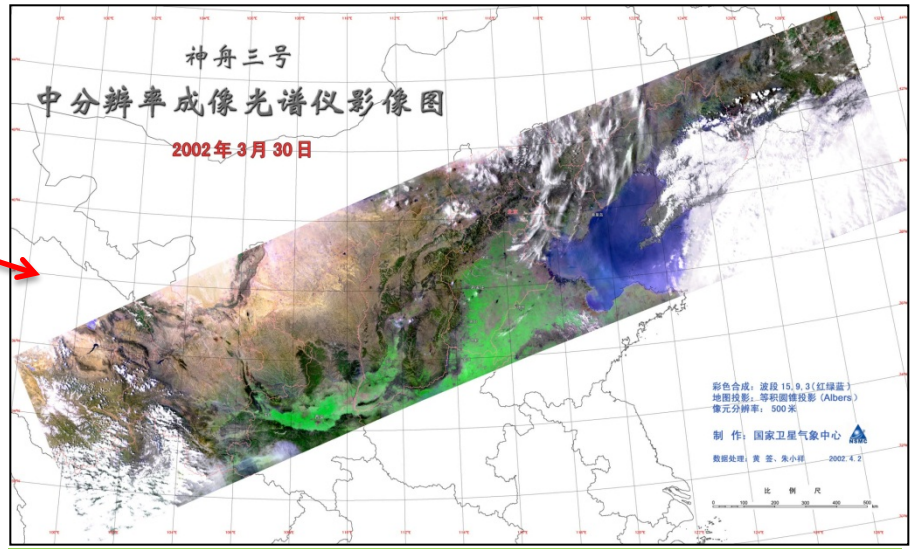
Sensor	Spectral Coverage /μm	Spectral Res. /nm	No. of Bands	Available Date
CMODIS	0.4-12.5	20	34	2002
HJ-1A HSI	0.45–0.95	5	115	2008
FY-3 MERSI	0.44–0.89 0.39–1.04 1.62-2.15 10-12.5	50 20 50 2500	5 12 2 1	2008
Chang'E-1 IIM	0.48-0.96	15	32	2009
TG-1 HSI	0.40-1.0 1.0-2.5	10 23	128	2011
SPARK	0.40-1.0	5	148	2016

Onboard Chinese Hyperspectral Missions

CMODIS: first satellite hyperspectral imager

- No. bands: 34, Include:
- Visible: 20 (20nm, from 412 nm)
- NIR: 10 (20nm, from 822 nm)
- SWIR: 1 (2.150-2.250 μm)
- TIR: 3

(8.40-8.90,10.30-11.30 μm,11.50-12.50 μm）

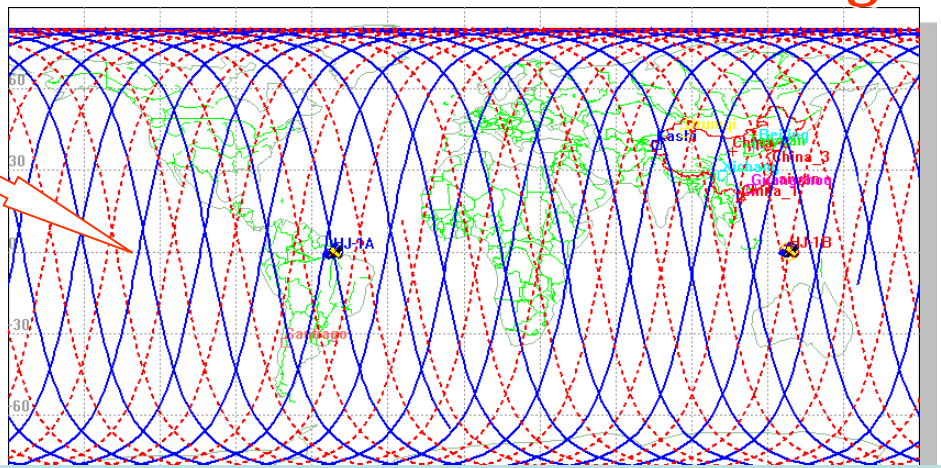


A typical CMODIS image

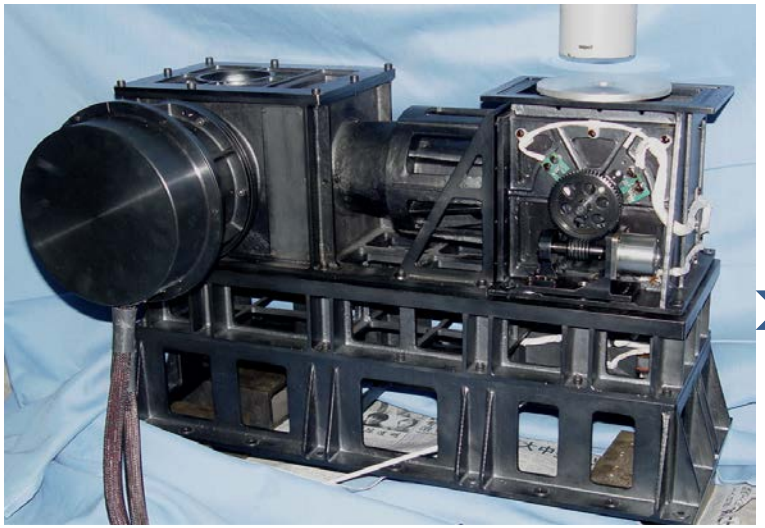
Onboard Chinese Hyperspectral Missions

CHJ-1A HSI （China，2008）

A Constellation of 2 Small Satellites (HJ-1) was launched in Sept. 6, 2008 for Environment and Disasters Monitoring



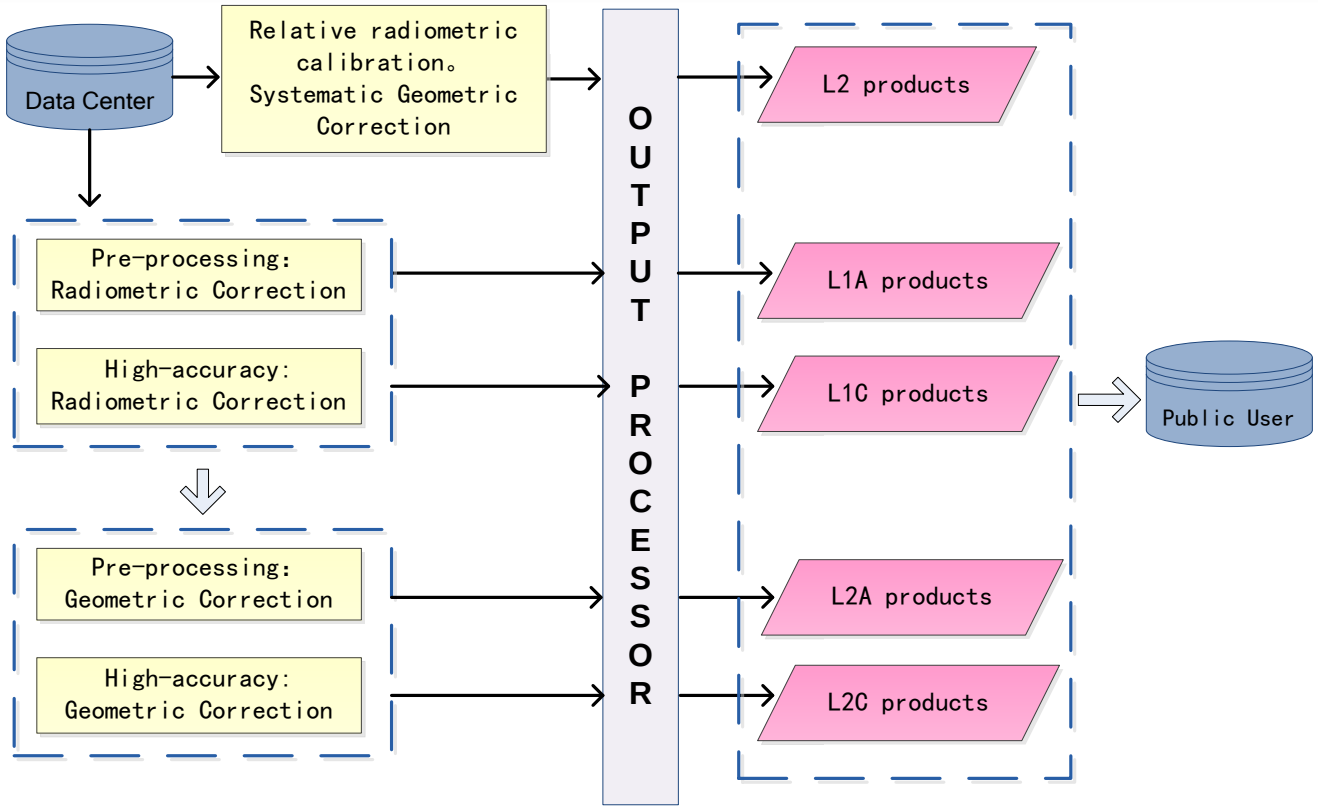
One of the Main Payloads on Board of the Satellite is a VIS-NIR Imaging Spectrometer (HSI)



Spec.Range: 450nm-900nm
Number of Bands: 115
Spatial Resolution: 100m
Ground Coverage: 50km
Side Looking： ±30°
Revisit： 4-31days

Onboard Chinese Hyperspectral Missions

HJ-1A HIS（China，2008）



Radiometric Correction：Data analysis、Homogenization、Noise remove、CCD mosaic、Bands co-registration.

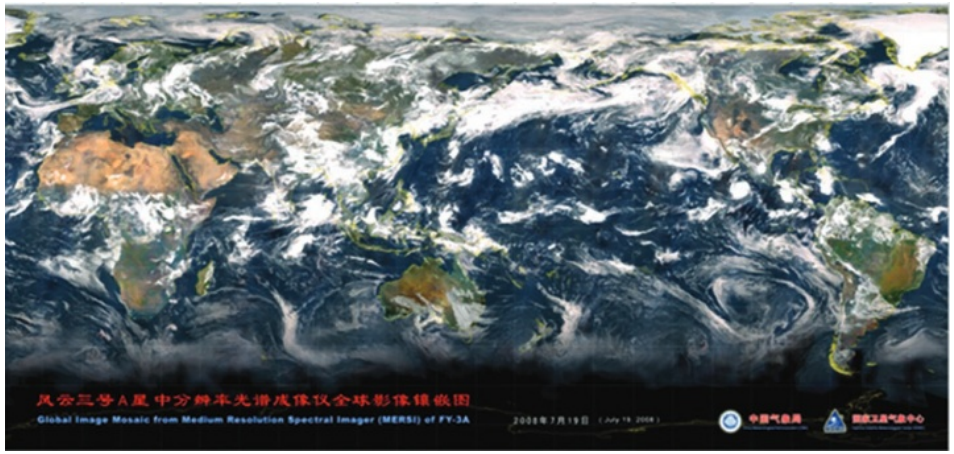
Geometric Correction：Geometric correction、Generating map projection.

Systematic Correction：Eliminating the influence of Attitude and Orbit parameter changes.

Onboard Chinese Hyperspectral Missions

MERSI/ FY-3A

Launched in 2008



A global image mosaic from MERSI with natural color and resolution of 3 km

(Courtesy: Chaohua Dong *et al.*)

Spec.Range: 0.4-12.5um	Number of Bands: 20
Spatial Resolution: 0.25-1km	Scanning range: ±55.4°
Quantization: 12 bit	Radiometric calibration Accu. <7%

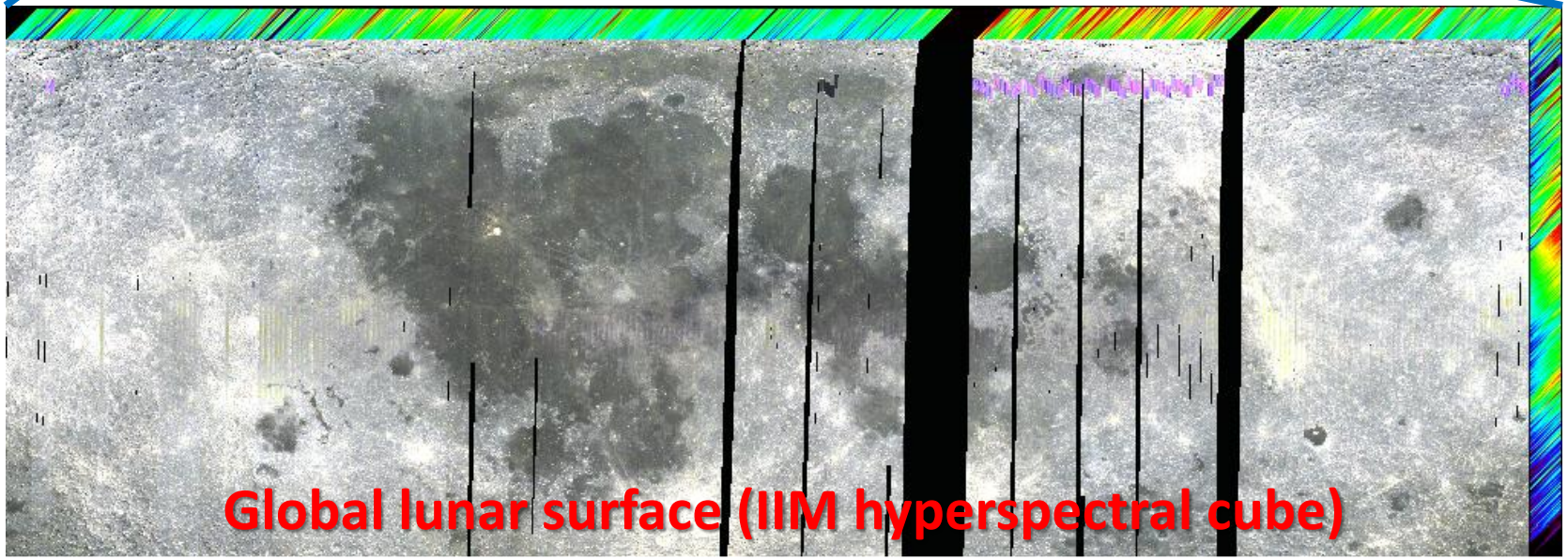
Assembling two onboard calibration systems

Onboard Chinese Hyperspectral Missions

Chang'E-1 IIM: for Lunar exploration

Width of Swath	25.6km
Spatial Resolution	200m
Imaging Region	75° N~75° S
Spectral Range	480~960nm
Spectral Bands	32
Digitazation	12bit
MTF	≥0.2

24-Oct-2007



Global lunar surface (IIM hyperspectral cube)

Onboard Chinese Hyperspectral Missions

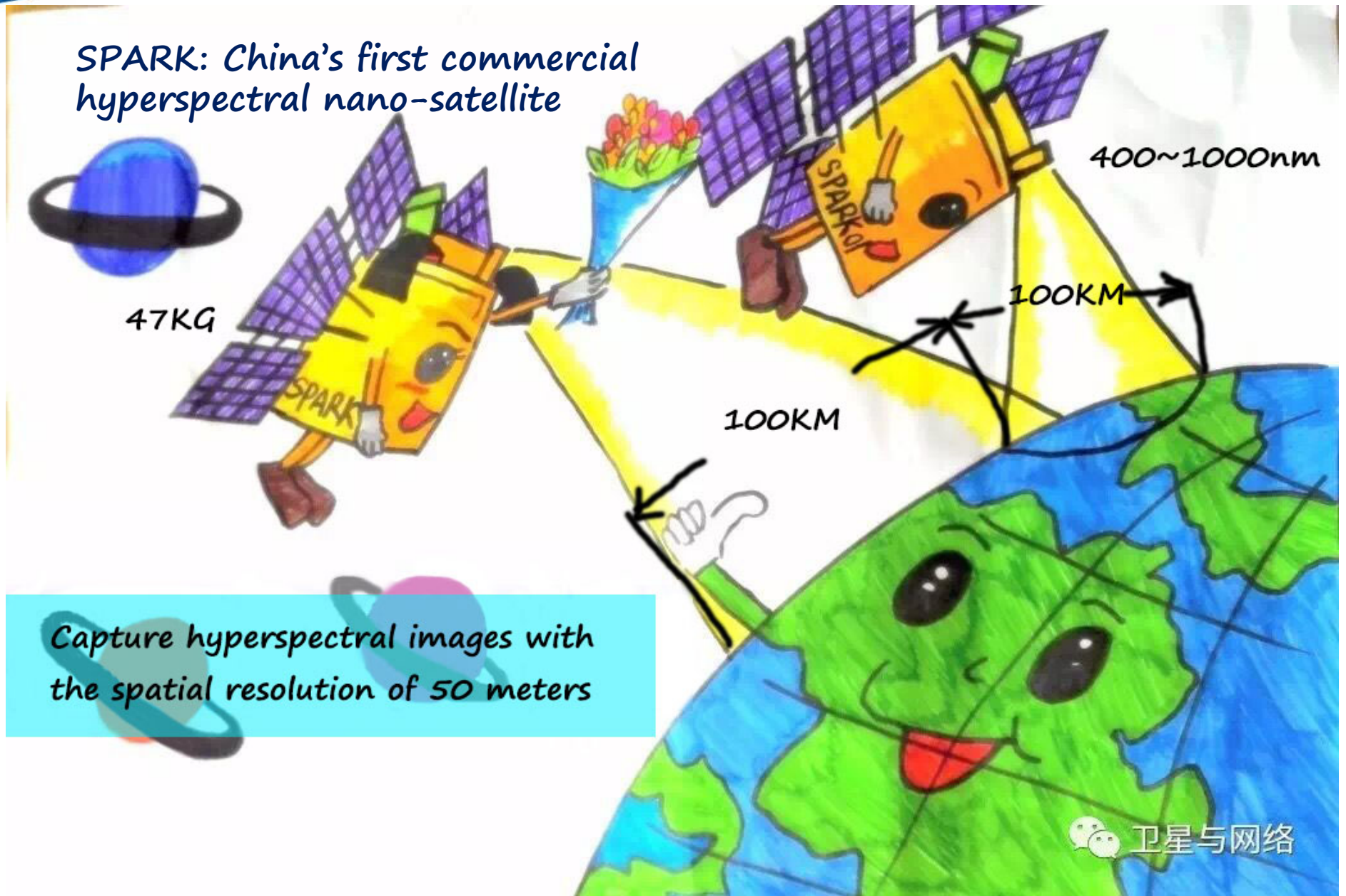
TG-1 HSI: China's first target vehicle

Spectral Coverage /nm	400-2500
Spectral Res. /nm	10/23
No. of Bands	128
MTF	0.34
Swath/km	10
SNR	180@1600nm

TG-1 Image, South Australia

OUTLINE

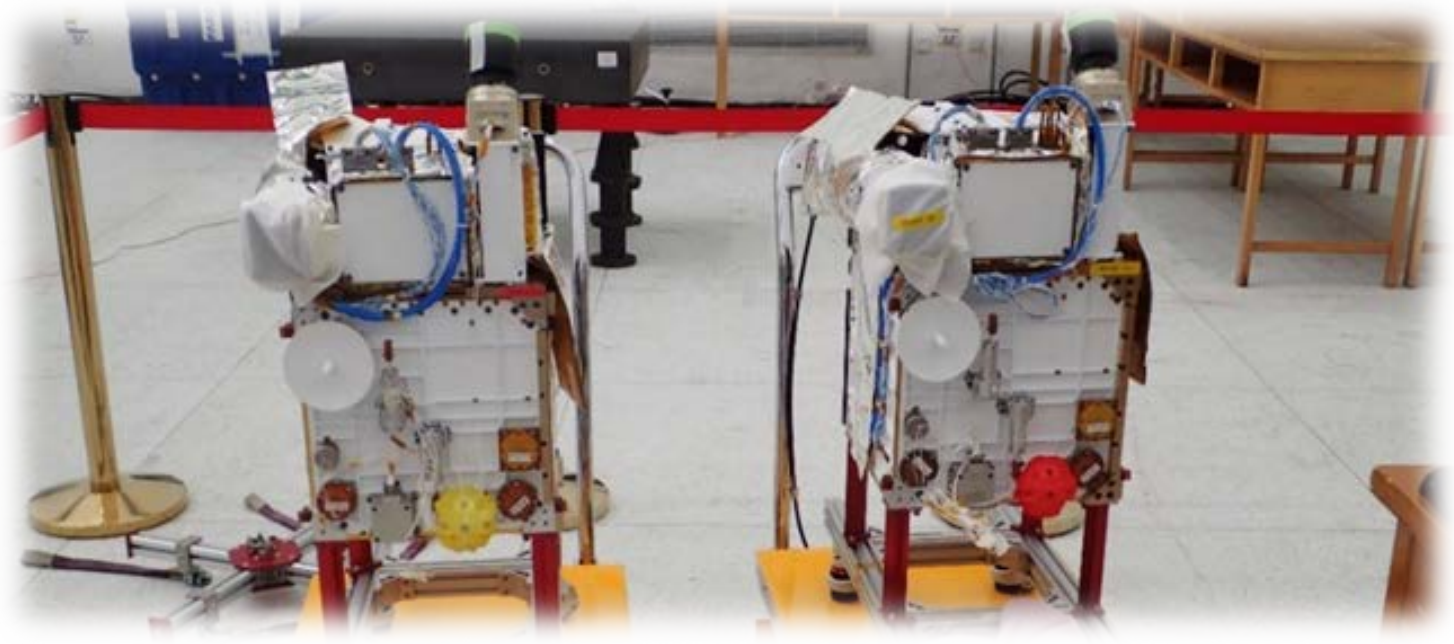
New Spaceborne Imaging Spectroscopy



New Spaceborne Imaging Spectroscopy

SPARK: China's first commercial hyperspectral nano-satellite

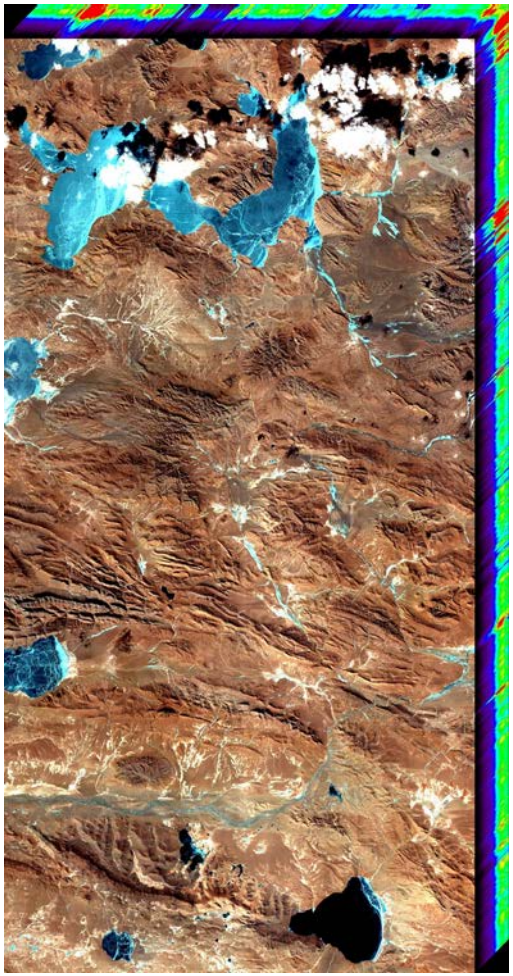
- **The first commercial hyperspectral nano satellite (SPARK-01、SPARK-02) were launched on December 22, 2016**



SPARK-01 **SPARK-02**

New Spaceborne Imaging Spectroscopy

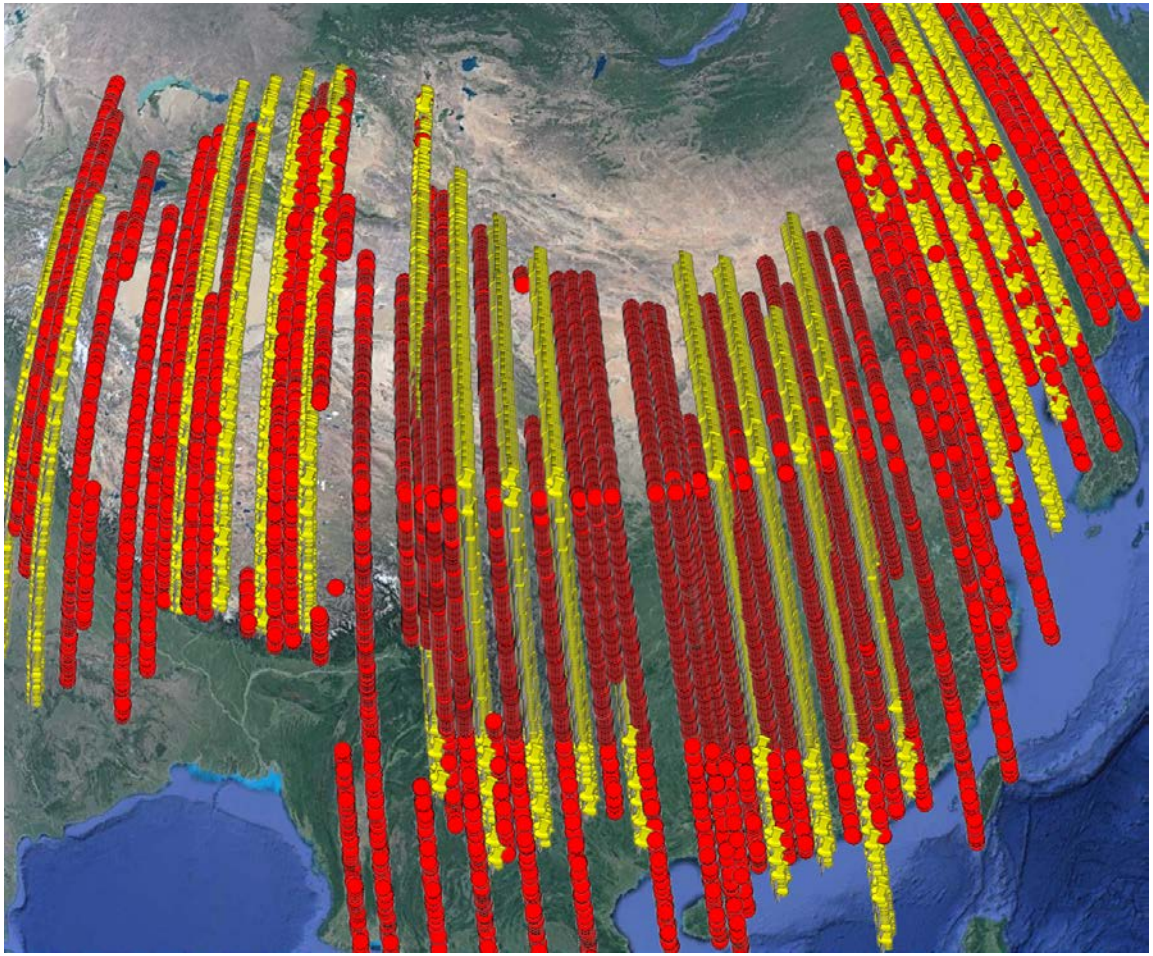
- **SPARK: China's first commercial hyperspectral nano-satellite**
  - Swath： 100km@700km;
  - Revisit period: 16 days;
  - Spatial resolution: 50m@700km；
  - Spectral range： 420~1000nm；
  - Number of band： 148；
  - Spectral resolution: 4nm；
  - Weight： 42kg；



The first image product of SPARK-02

New Spaceborne Imaging Spectroscopy

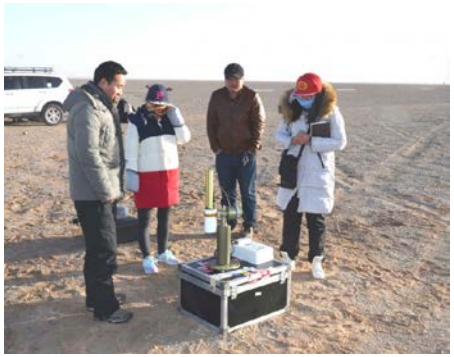
Strong data acquisition ability of SPARK



The images obtained by SPARK in the region of China within two months .

New Spaceborne Imaging Spectroscopy

Radiation calibration of SPARK data



SPARK satellite

On-orbit calibration preparation

Relative radiometric calibration

Dark current calculation

Based on rectilinear flight

Geometric correction

Absolute radiometric calibration

Based on the reflectivity method

Error estimation based on radiative transfer model

Ground reflectance error

Optical thickness error

Aerosol error

Water vapor error

Atmospheric model error

SNR error

Other errors

End of the calibration

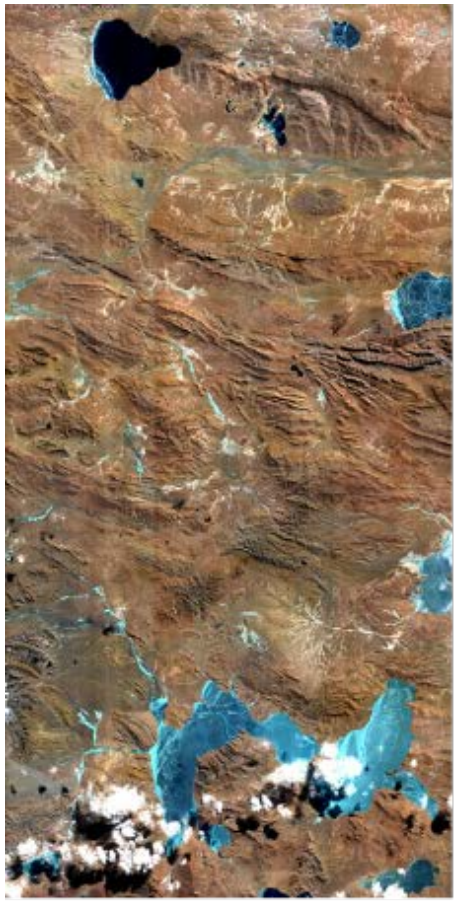
New Spaceborne Imaging Spectroscopy

Data products of SPARK

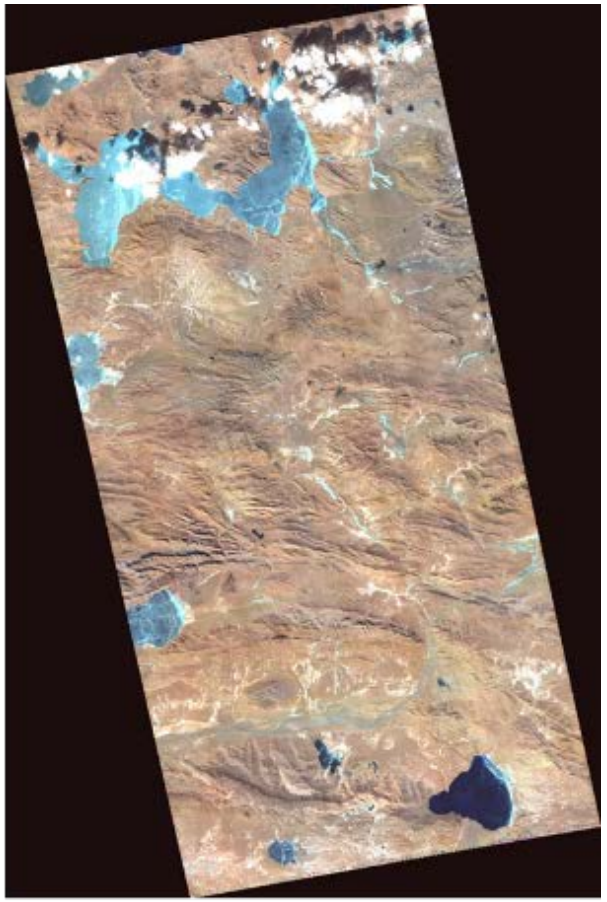
Product level		Definition
Level 0		Data decompression, data cutting out and disparting products
Level 1	L1A	Relative radiometric correction products based on L0
	L1B	Absolute radiometric calibration and spectral calibration products based on L1A
	L1C	Atmospheric correction products based on L1B
Level 2	L2A	Systematically geometric correction products based on L1A
	L2B	Systematically geometric correction products based on L1B
	L2C	Systematically geometric correction products based on L1C
Level 3	L3A	Geometric accurate correction products based on L2A
	L3B	Geometric accurate correction products based on L2B
	L3C	Geometric accurate correction products based on L2C
Level 4	L4	Orthographic correction products
Level 5	L5	Mosaic and fusion products
Special application products		Typical application products such as agriculture, forestry, water environmental

New Spaceborne Imaging Spectroscopy

Data products of SPARK



L1B



L2B

New Spaceborne Imaging Spectroscopy

Applications of SPARK data

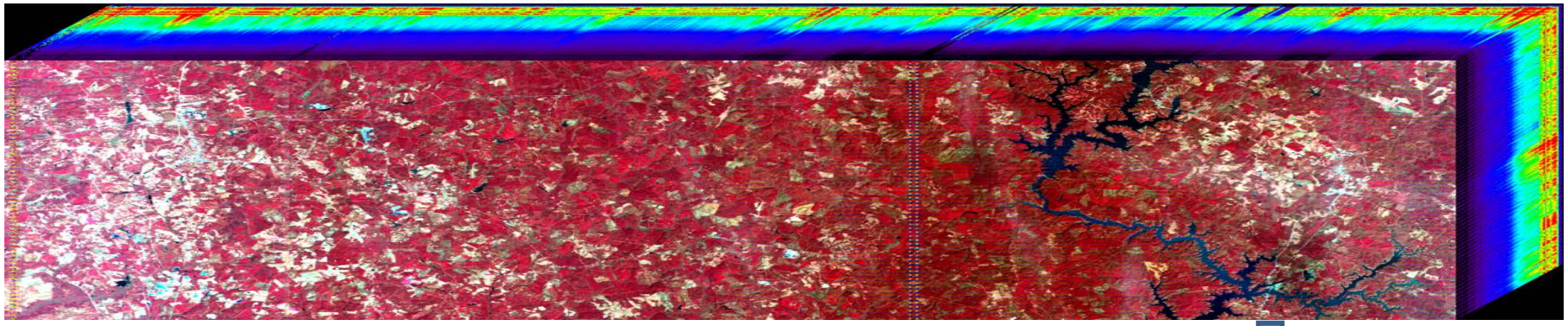
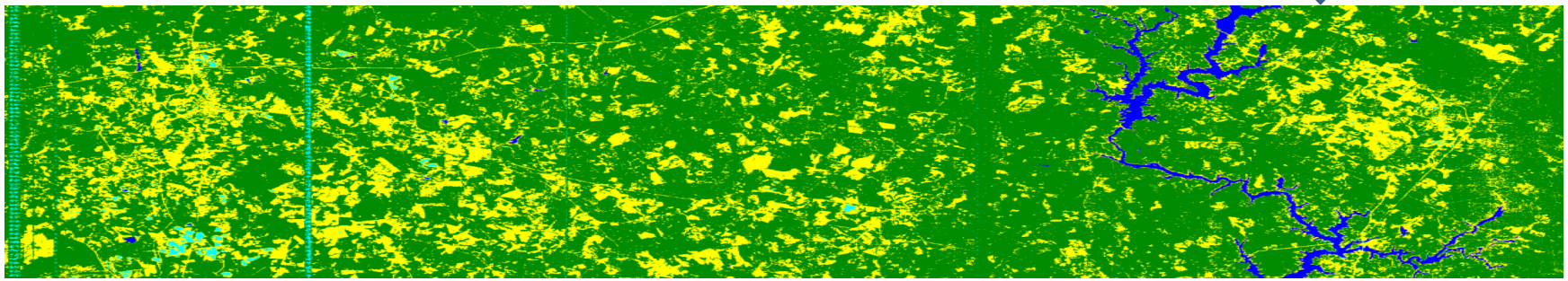


Image data captured by SPARK-02 (Putnam County, Georgia, America)

Classification

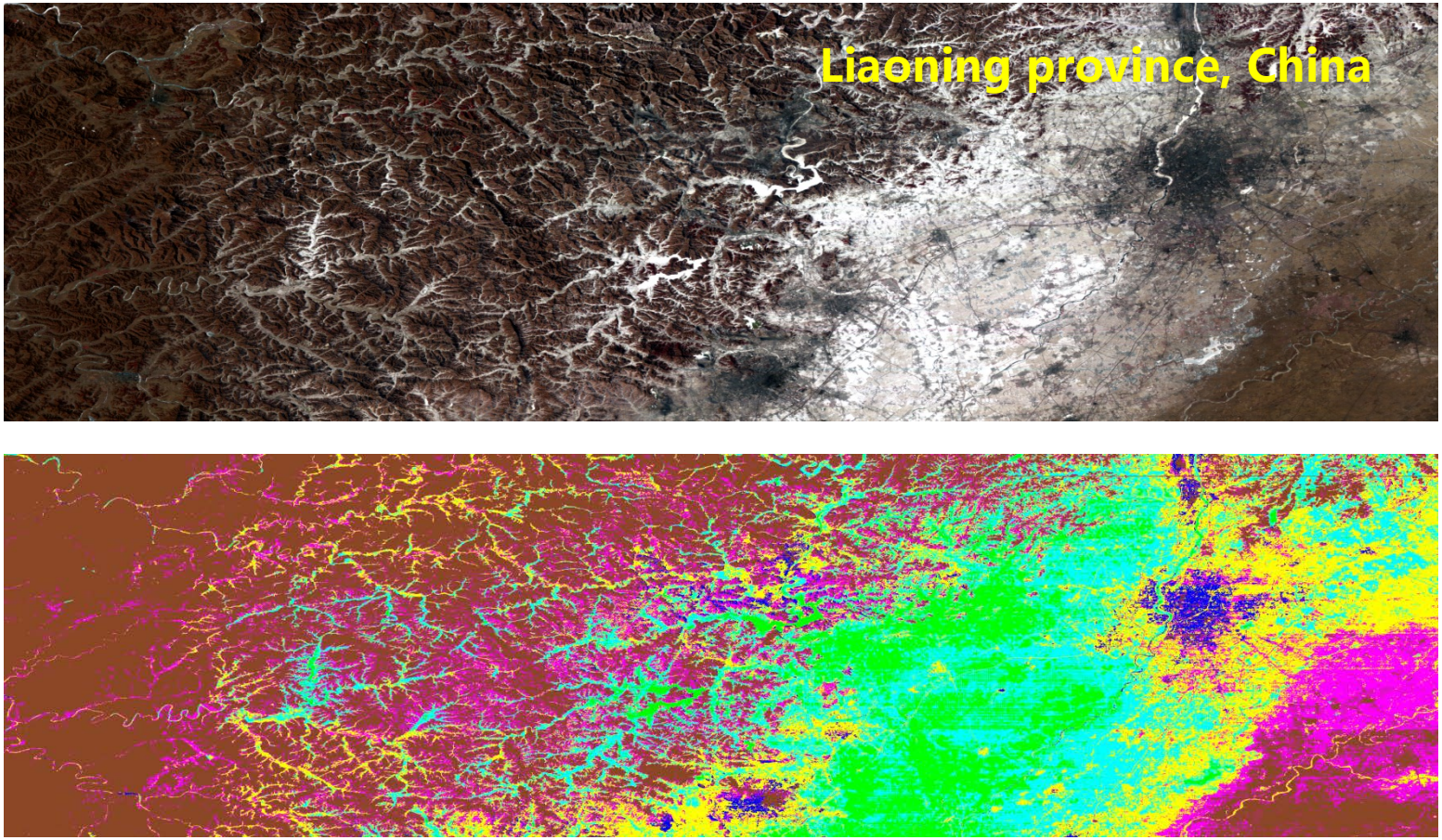


Vegetations | Man-made features | Water

Classification based on hyperspectral features

New Spaceborne Imaging Spectroscopy

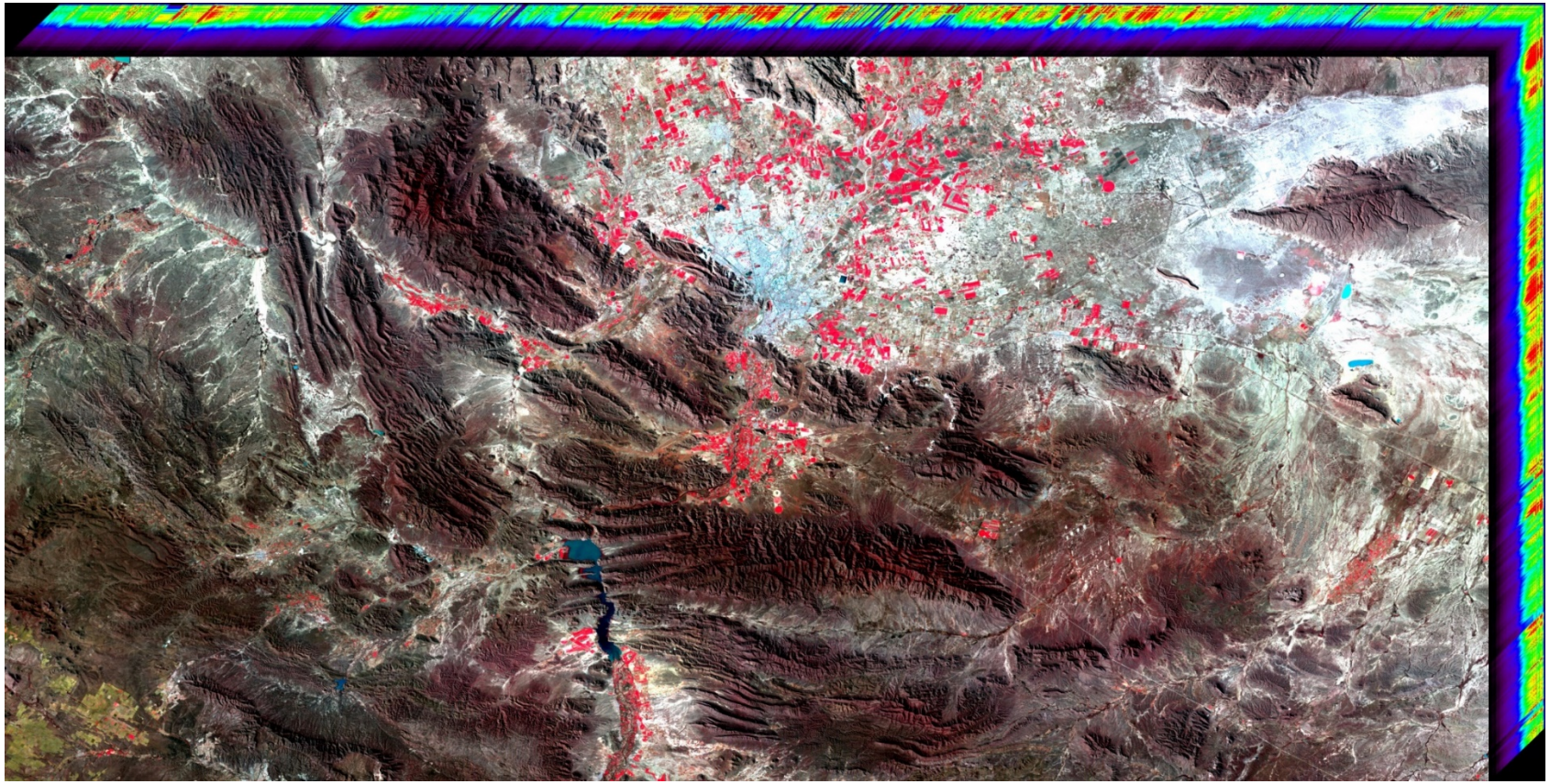
Applications of SPARK data



Wide range of land use monitoring

New Spaceborne Imaging Spectroscopy

Applications of SPARK data



Complex terrain area - investigation of vegetation distribution

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Upcoming Hyperspectral Missions

GF-series: high-resolution satellite program

GF-3 (2016)
- CSAR

GF-4 (2015)
- 50m-geostationary

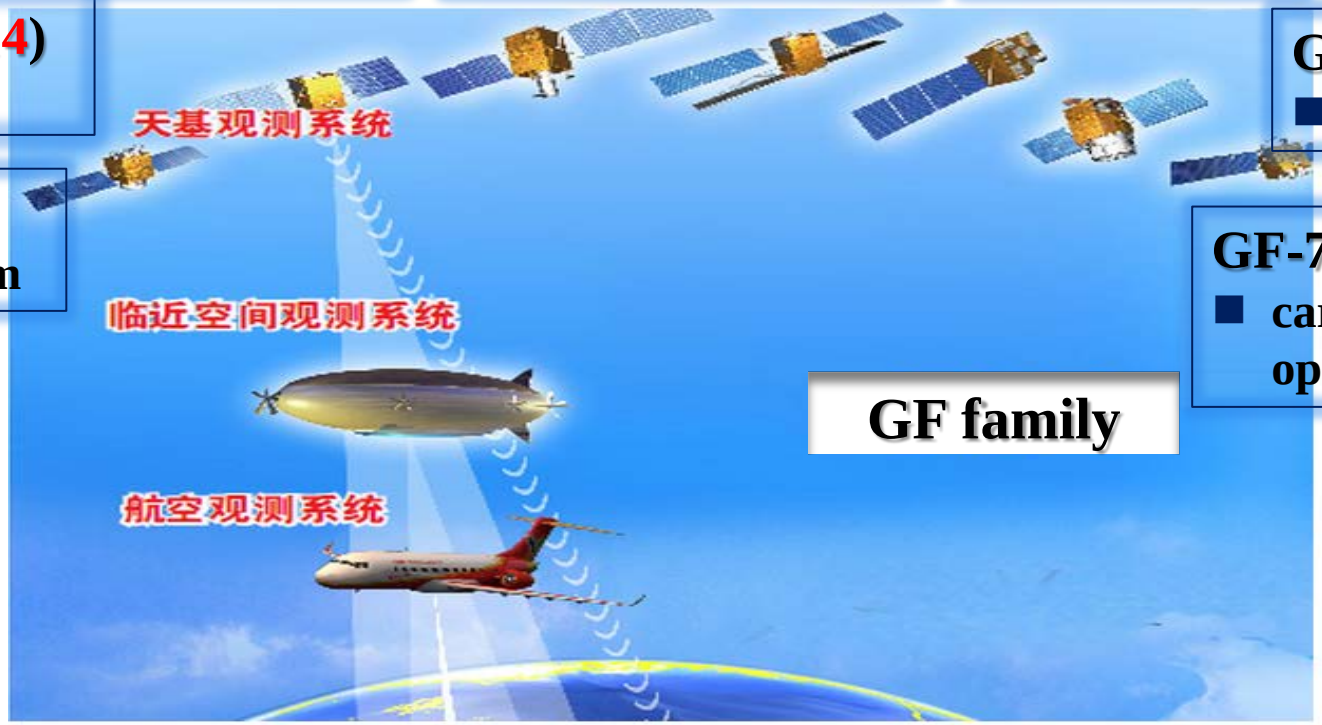
GF-5 (2017)
- HRS

GF-2 (2014)
- 1m/4m

GF-6 (2017)
- Like GF-1

GF-1 (2013)
- 2m/8m/16m

GF-7 (2018)
- cartographic optical satellite



The GF project indicates that Chinese Earth observation enters high-resolution phase

Upcoming Hyperspectral Missions

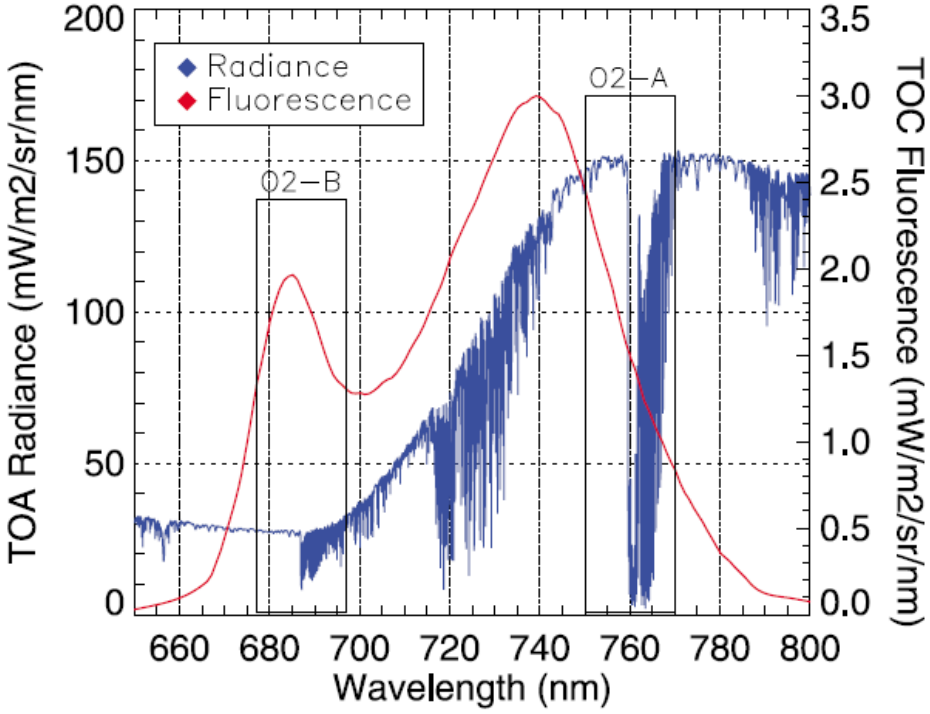
GF-5

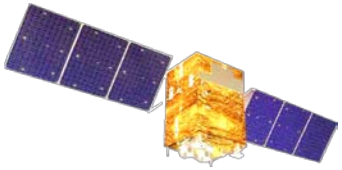
Sensors / Para.	HyperSpectral Camera (VNIR、SWIR)	Full-spectrum spectral imager	Greenhouse gas detector	Atmospheric environment NIR hyspectral detector	Atmospheric-trace-gas absorption spectrometer	Aerosol Multi-angle polarization detectors
Spec. range	**VNIR:** 0.4μm-0.9μm **SWIR1:** 0.9μm-1.75μm **SWIR2:** 1.75μm-2.5μm	0.45μm | | 12.5μm	0.765μm（O_2） 1.575μm（CO_2） 1.65μm（CH_4） 2.05μm（CO_2）	750～4100cm^{-1} （2.4～13.3μm）	240～315nm 311～403nm 411～550nm 545～710nm	433-453nm 480-500nm（P） 555-575nm 660-680nm（P） 758-768nm 745-785nm 845-885nm（P） 900-920nm
Spec.Res	VNIR:5nm SWIR:10nm	0.06um~1.1um	0.6cm^{-1}（O_2）， 0.27cm^{-1}（CO_2、CH_4）	0.03cm^{-1}	0.3～0.5nm	
Spatial Res	30m	**VNIR:**20m **M-LWIR:**40m	IFOV : 14.6mrad	IFOV: 1.25mrad	48km（across orbit）×13km（orbit direction）	3.5km
Swath	60km	60km	--	--	--	--
SNR	**VNIR:**≥200 **SWIR1:**≥150 **SWIR2:**≥100	**VNIR:**≥200 **M-LWIR:** NE△T≤0.2K	≥300@p=30%（O_2，CO_2） ≥250@p=30%（CH_4，CO_2）	＞100（@5800K）	--	＞500（Land）

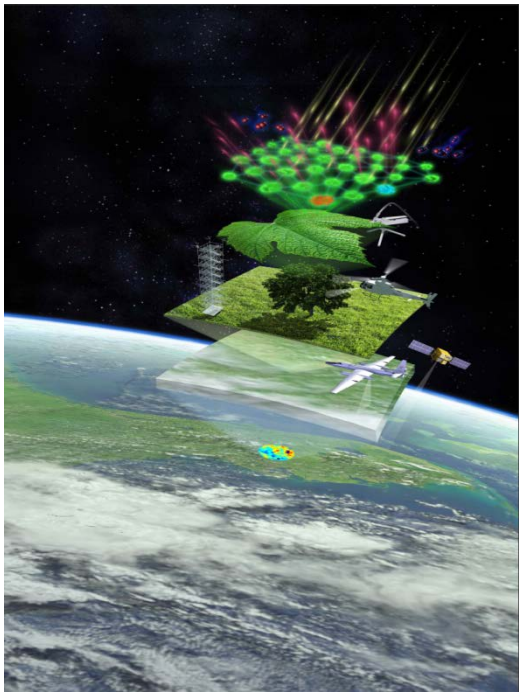
Upcoming Hyperspectral Missions

CarbonSat: Super-spectral spectrometer

Objective: Global carbon cycle monitoring by integrating vegetation reflectance and sun-induced fluorescence emission flux.







The finer the spectral resolution
The deeper the Fraunhofer Lines

A balance between SNR and Spectral resolution

Upcoming Hyperspectral Missions

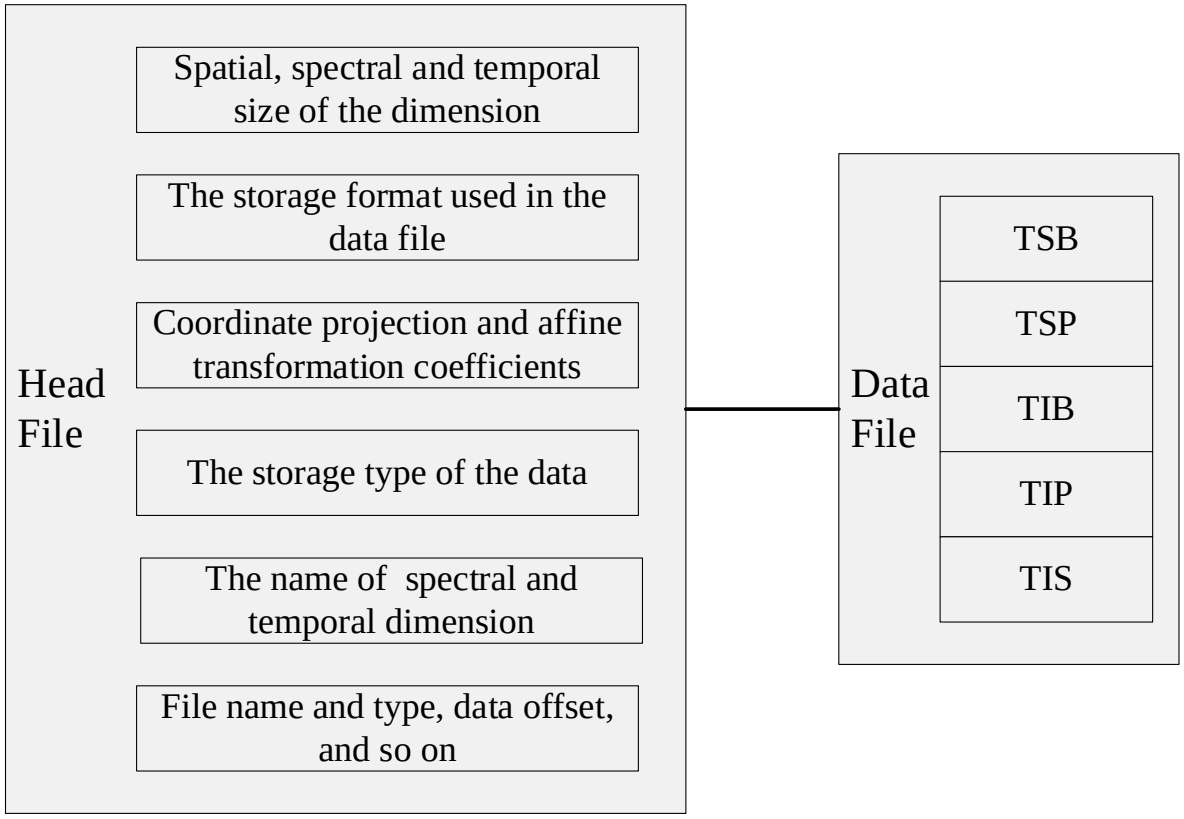
Space-borne sensors for SIF detection worldwide

Sensor Parameters	GOSAT	OCO-2	GOME-2	SCIAMACHY	CarbonSat
Data Acuqisition	Non-imaging	Non-imaging	Non-imaging	Non-imaging	Imaging
Launch time	2009	2014	2006	2002	2020
Overpass time	13：00	13：00	9:30	10:00	10:00
Visit circle	3 day	16 day	1.5 day	6 day	27 d
Spectral range	757 – 775 nm		650 – 790 nm		670 - 780 nm
FWHM	0.025 nm	0.05 nm	0.5 nm		~0.3 nm
Spatial resolution	10 km	1.3×2.25 km	40×80 km	30×40 km	300 m
SNR	>300 (30%, SZA=30^0)	360（5%, SZA=60^0）	> 1000	3000	> 200

Upcoming Hyperspectral Missions

New MDD format for time series image data storage

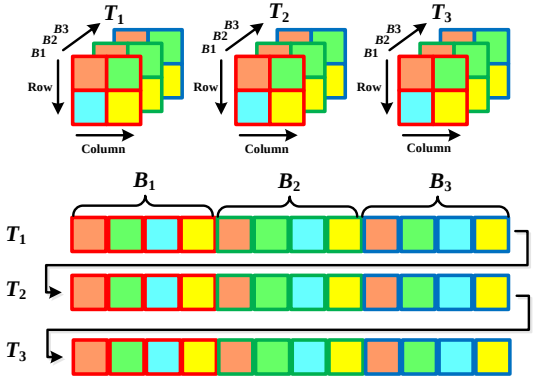
- **MDD is a multi-dimensional data storage format that can integrate the temporal, spatial, and spectral features of remote sensing data. The MDD has two files: a header file and a data file.**



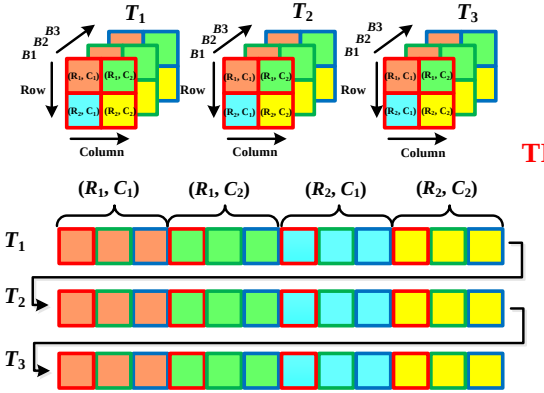
Upcoming Hyperspectral Missions

- New *.mdd multidimensional storage structures
  - 5 MDD structure, TSB,TSP,TIB,TIP,TIS

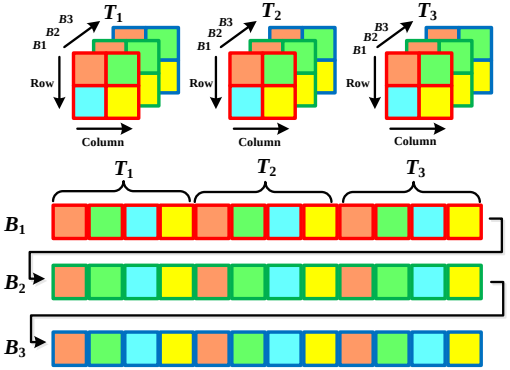
TSB



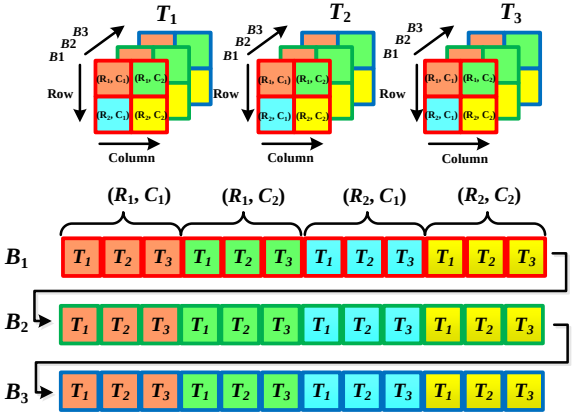
TSP



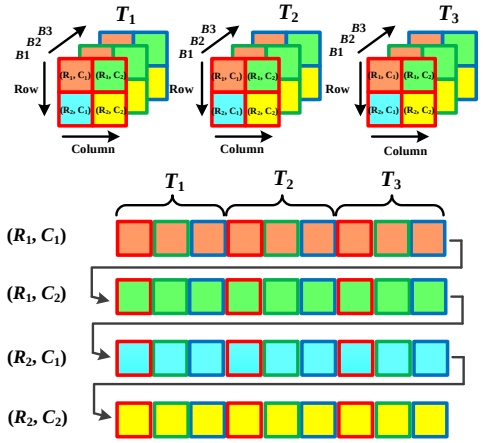
TIB



TIP



TIS

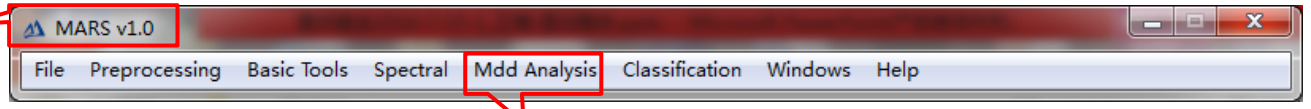


Upcoming Hyperspectral Missions

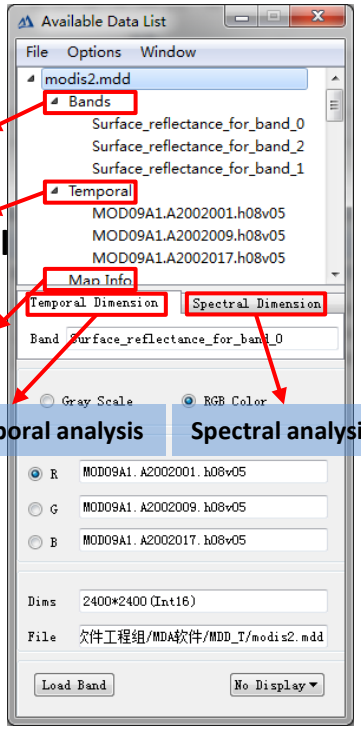
Multidimensional analysis software: MARS V1.0

MARS is a computer software, which can be used for MDD data building, opening, display, processing, analysis and output.

Free download for all users on the website: http://www.geodoi.ac.cn



Multi-dimensional analysis module



Spectral

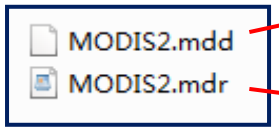
Temporal

Spatial

Temporal analysis

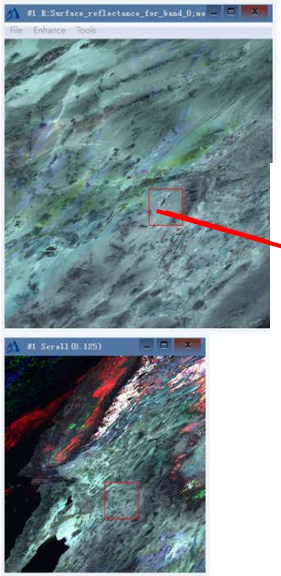
Spectral analysis

MDD data

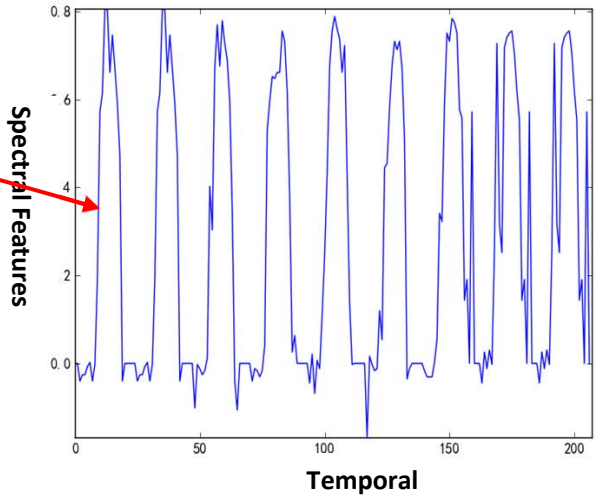


Data file

Header file



Visual Interface



Extraction of time series spectral features

Upcoming Hyperspectral Missions

OUTLINE

1. Introduction
2. Onboard Chinese Hyperspectral Missions
3. New Spaceborne Imaging Spectroscopy
4. Upcoming Hyperspectral Missions
5. Conclusions

Conclusions

- **What's new in 2016 and 2017:**
  - China launched the first commercial hyperspectral nano-Satellite: SPARK, in 2016;
  - Chinese GF-5 hyperspectral satellite will be launching in Aug. 2017;
  - Chinese Carbon Satellite is undergoing demonstration research;
  - We defined a new multidimensional remote sensing data structure for time-series analysis;
  - We published our multidimensional analysis software, which can be download at

    http://www.geodoi.ac.cn/WebEn/doi.aspx?Id=702

Thank you !

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