FY-3C VIRR /MERSI Geolocation and Fengyun Satellite Program Future Plan

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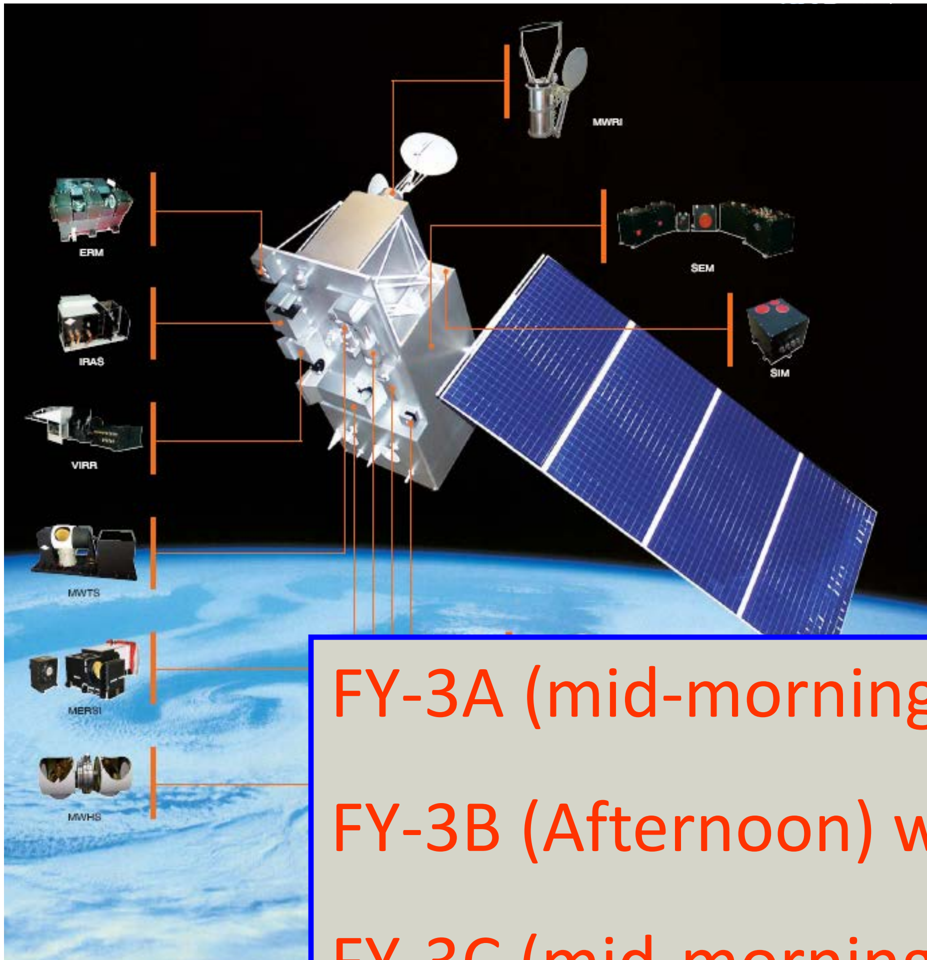
Outline

- Introduction
- Instrument Geometry
- Geolocation algorithm and Error analysis
- On-Orbit Geometric Characterization
- FengYun satellite Program and its Future Plan
- Conclusions

Fengyun LEO

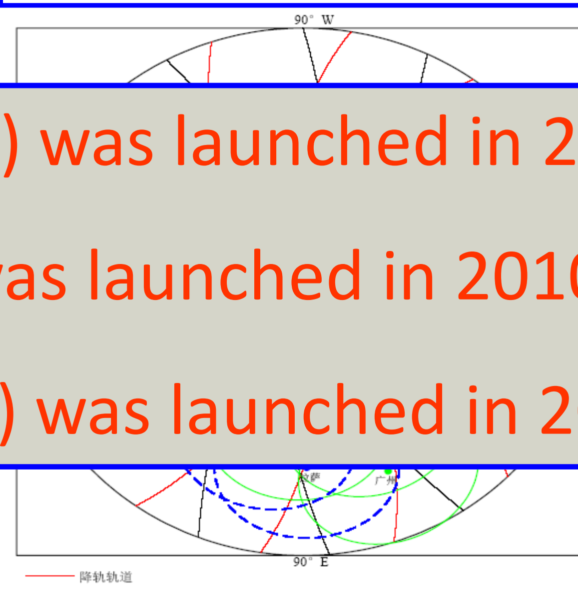
- ■FY-1: Retired
- ■FY-3: 2nd Generation



Prototype structure of FY-3

FY-3 has 11 Instruments

- ✓Atmospheric sounding
- ✓Microwave Imaging
- ✓ Ozone sounding
- ✓ Radiation budget for Earth system
- ☐Spatial Resolution from 1 Km to 250m
- ☐Global data acquisition latency : 1.5 hours



FY-3A (mid-morning) was launched in 2008,

FY-3B (Afternoon) was launched in 2010,

FY-3C (mid-morning) was launched in 2013.

FY-3C Configuration

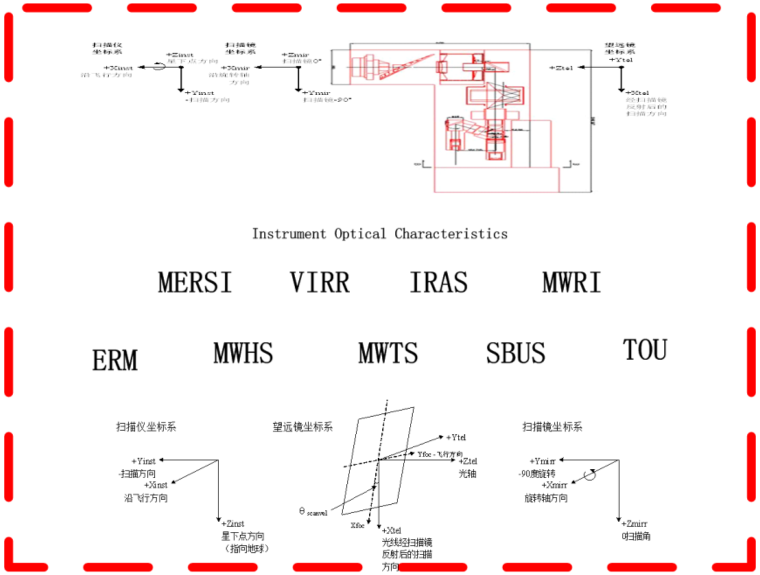
- Provide important meteorological products, for weather forecasting, climate research, disaster monitoring and environmental monitoring.
- VIRR and MERSI (250m/1km spatial resolution) are two important payloads with the spectral bands covering visible, near-infrared and infrared spectral ranges.

FY-3 OPERATIONAL SATELLITE INSTRUMENTS	FY-3C
MERSI – Medium Resolution Spectral Imager (I, II)	√(I)
MWTS – Microwave Temperature Sounder (II)	√
MWHS – Microwave Humidity Sounder (II)	√
MWRI – Microwave Radiation Imager	√
WindRAD - Wind Radar	
GAS - Greenhouse Gases Absorption Spectrometer	
HIRAS – Hyper spectral Infrared Atmospheric Sounder	
OMS – Ozone Mapping Spectrometer	
GNOS – GNSS Occultation Sounder	√
ERM – Earth Radiation Measurement (I, II)	√(I)
SIM – Solar irritation Monitor (I, II)	√(I)
SES – Space Environment Suite	√
IRAS – Infrared Atmospheric Sounder	√
VIRR – visible and Infrared Radiometer	√
SBUS – Solar Backscattered Ultraviolet Sounder	√
TOU – Total Ozone Unit	√

FY-3C Image Geolocation

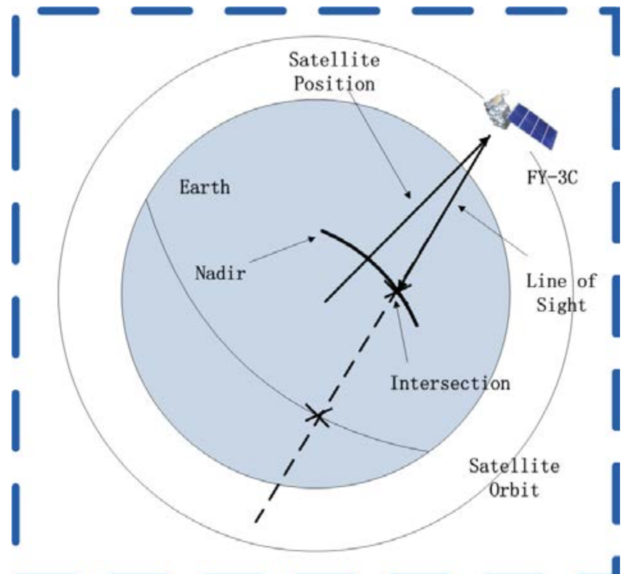
FY-3C was launched on 23th Sep. 2013. All 9 payloads' data geolocation have been done with multi-thread in the ground operational system.

Instrument Level



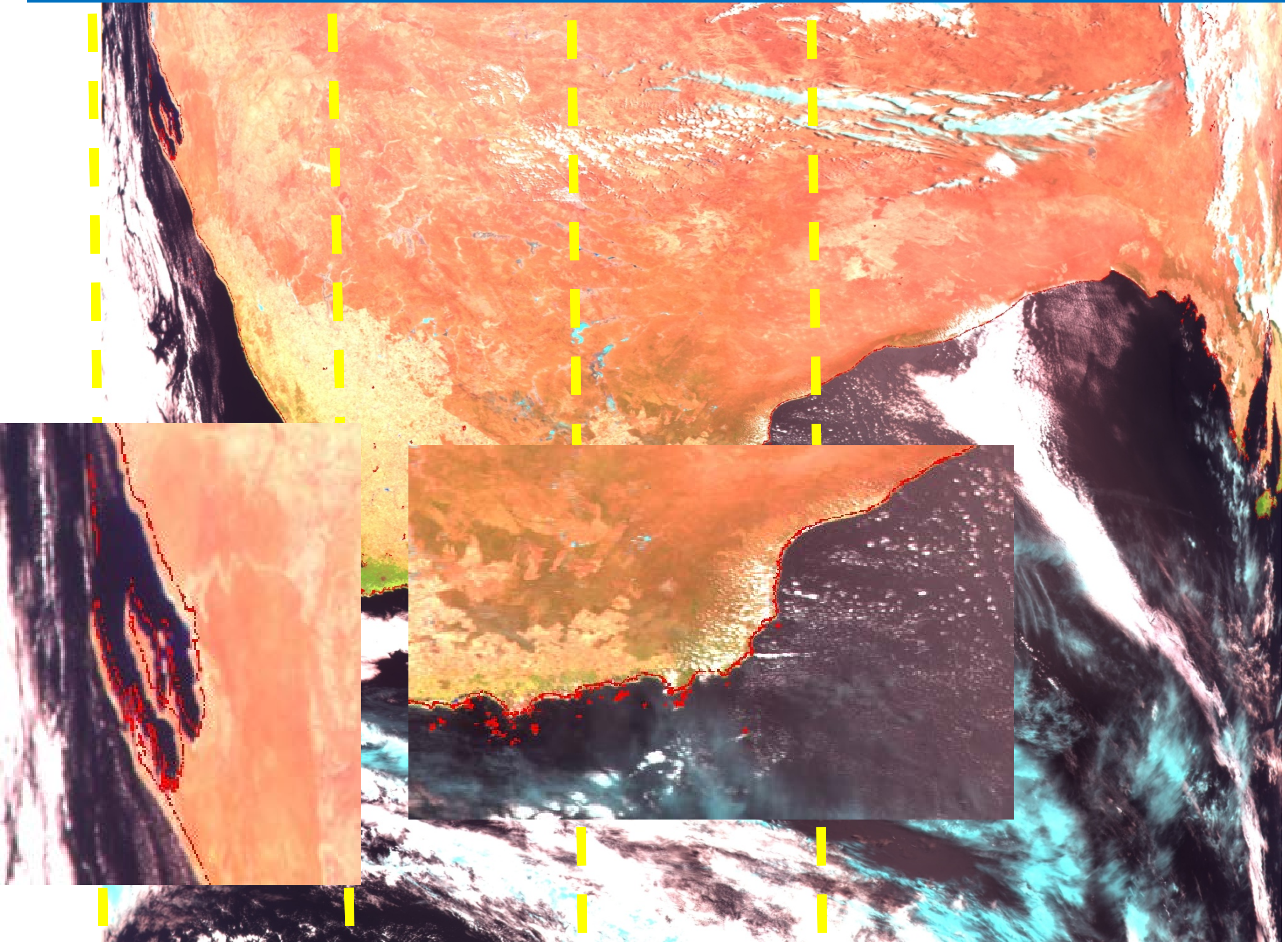
Line of sight

Satellite Level



Intersection between the Line of sight and the Earth Figure

FY-3A/B geolocation has achieved 1 pixel at sub-satellite point. But there is still some errors in the edge of the orbit.



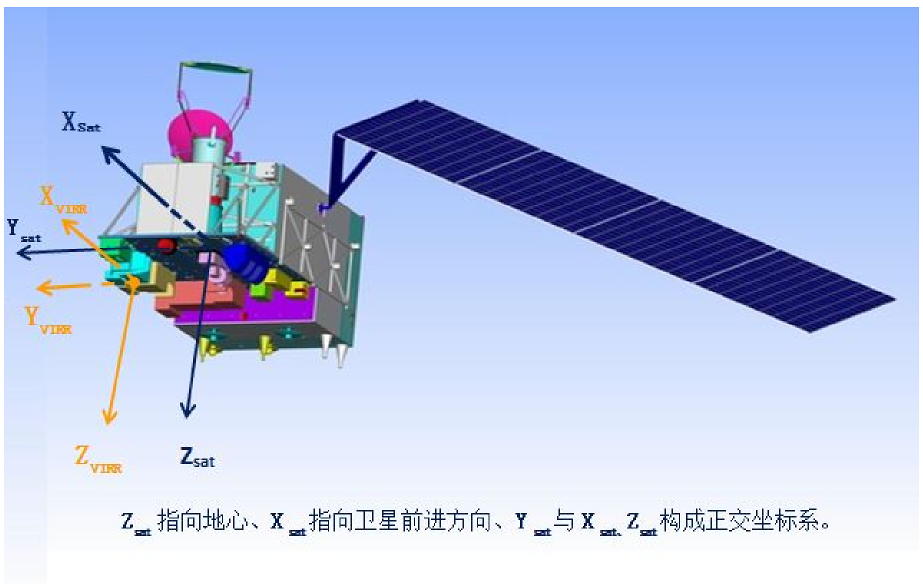
FY-3C Geolocation Error

Main Error：

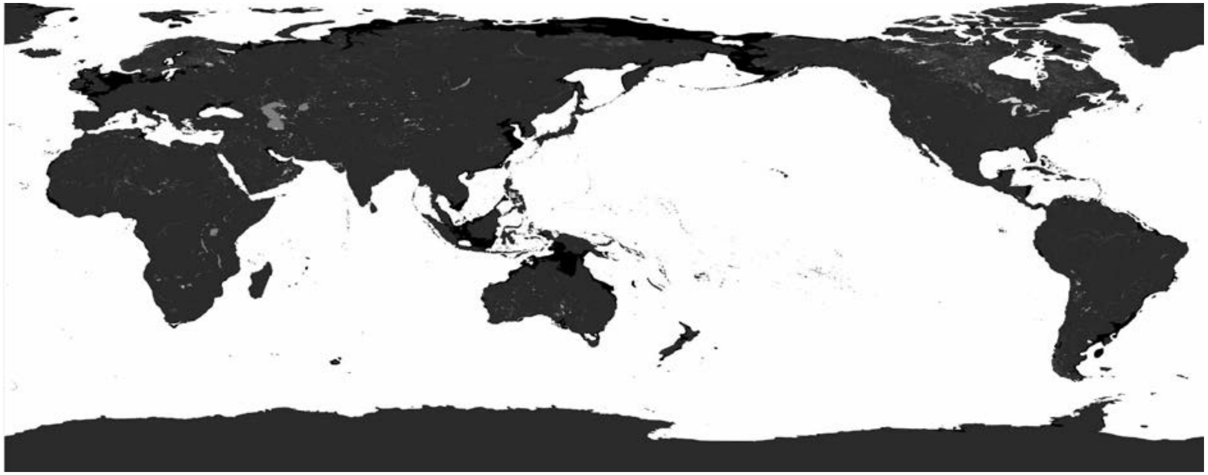
1、**GPS Measurement** 20~50m
2、**Star Trackers** 15’’->0.125km
3、**Time** 40m

} 1/5 pixel

4、**Mis-alignment** Main Err Source



$$T_{inst2Sat} = R_y(\theta)R_x(\varphi)R_z(\psi) = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$



Global landmark

Hainan Island

Table 1 FY-3C VIRR Mis-alignment Matrix Update

Parameter (arcsec)	At Launch (27th Sep. 2013)	First Update (27th Nov. 2013)	Second Update (19th Dec. 2014)
Roll	410.4	273.6	123.1
Pitch	0	342	328.3
Yaw	0	0	0

Table 2 FY-3C MERSI Mis-alignment Matrix Update

Parameter (arcsec)	At Launch (27th Sep. 2013)	First Update (2nd Oct. 2013)	Second Update (29th Dec. 2014)
Roll	993.6	993.6	621.0
Pitch	-993.6	-993.6	-968.76
Yaw	0	0	0

FY-3C Geolocation

Equation：

Mis-alignment

$$\begin{bmatrix} 0 & f_{3i}(\theta,\varphi) & -f_{2i}(\theta,\varphi) \\ -f_{3i}(\theta,\varphi) & 0 & f_{1i}(\theta,\varphi) \\ f_{2i}(\theta,\varphi) & -f_{1i}(\theta,\varphi) & 0 \end{bmatrix} \begin{bmatrix} \xi_{ri} \\ \xi_{pi} \\ \xi_{yi} \end{bmatrix} - \begin{bmatrix} u_{xi} - f_{1i}(\theta,\varphi) \\ u_{yi} - f_{2i}(\theta,\varphi) \\ u_{zi} - f_{3i}(\theta,\varphi) \end{bmatrix} = \begin{bmatrix} \varepsilon_{ri} \\ \varepsilon_{pi} \\ \varepsilon_{yi} \end{bmatrix}$$

To min: $\min \sum_{i=1}^{N} (\varepsilon_{ri}^2 + \varepsilon_{pi}^2 + \varepsilon_{yi}^2)$ $\quad i = 1,2,\ldots,N$ **landmark**

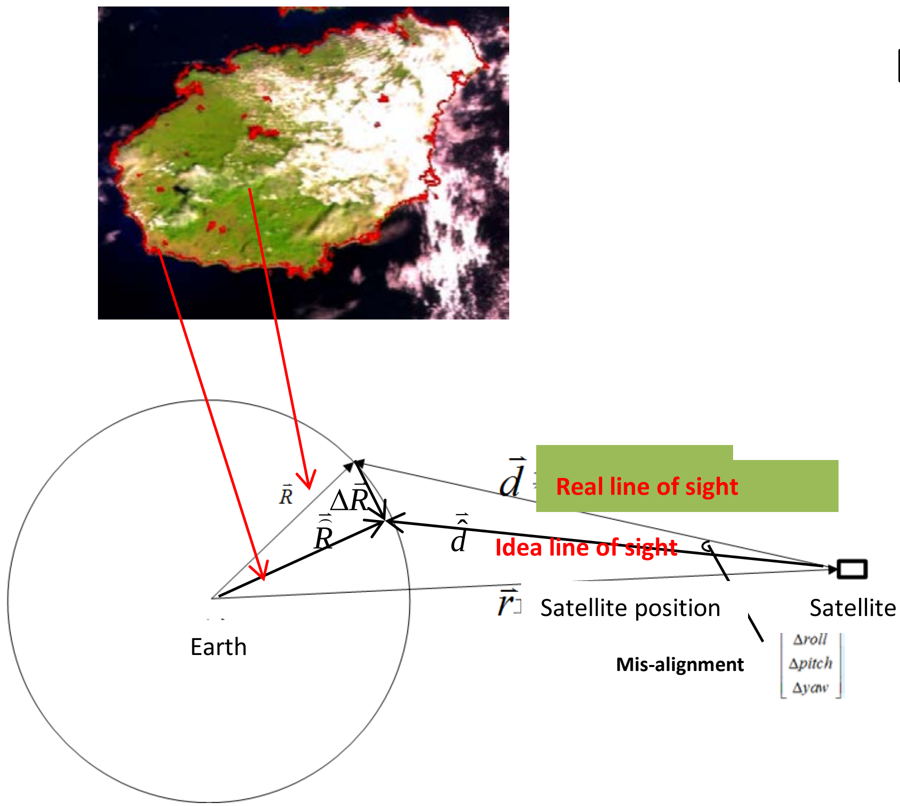


Fig.1 Mis-alignment Parameters Equation

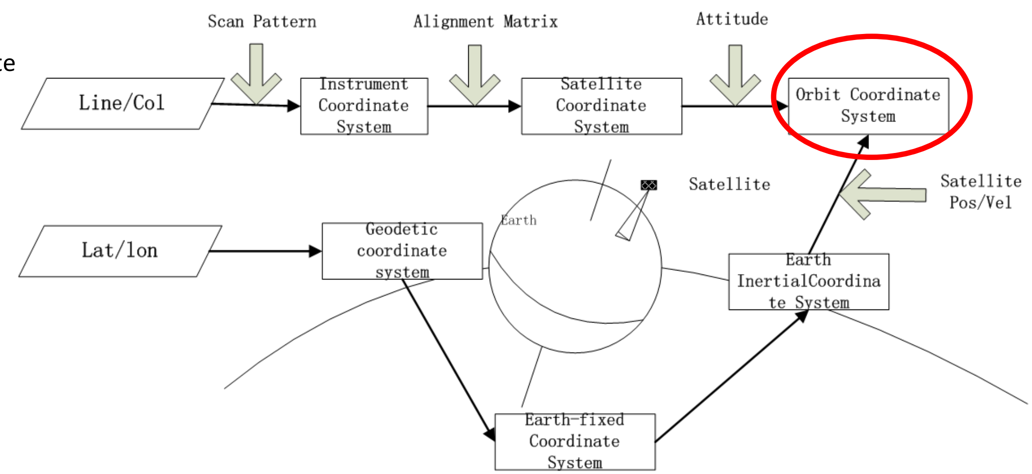
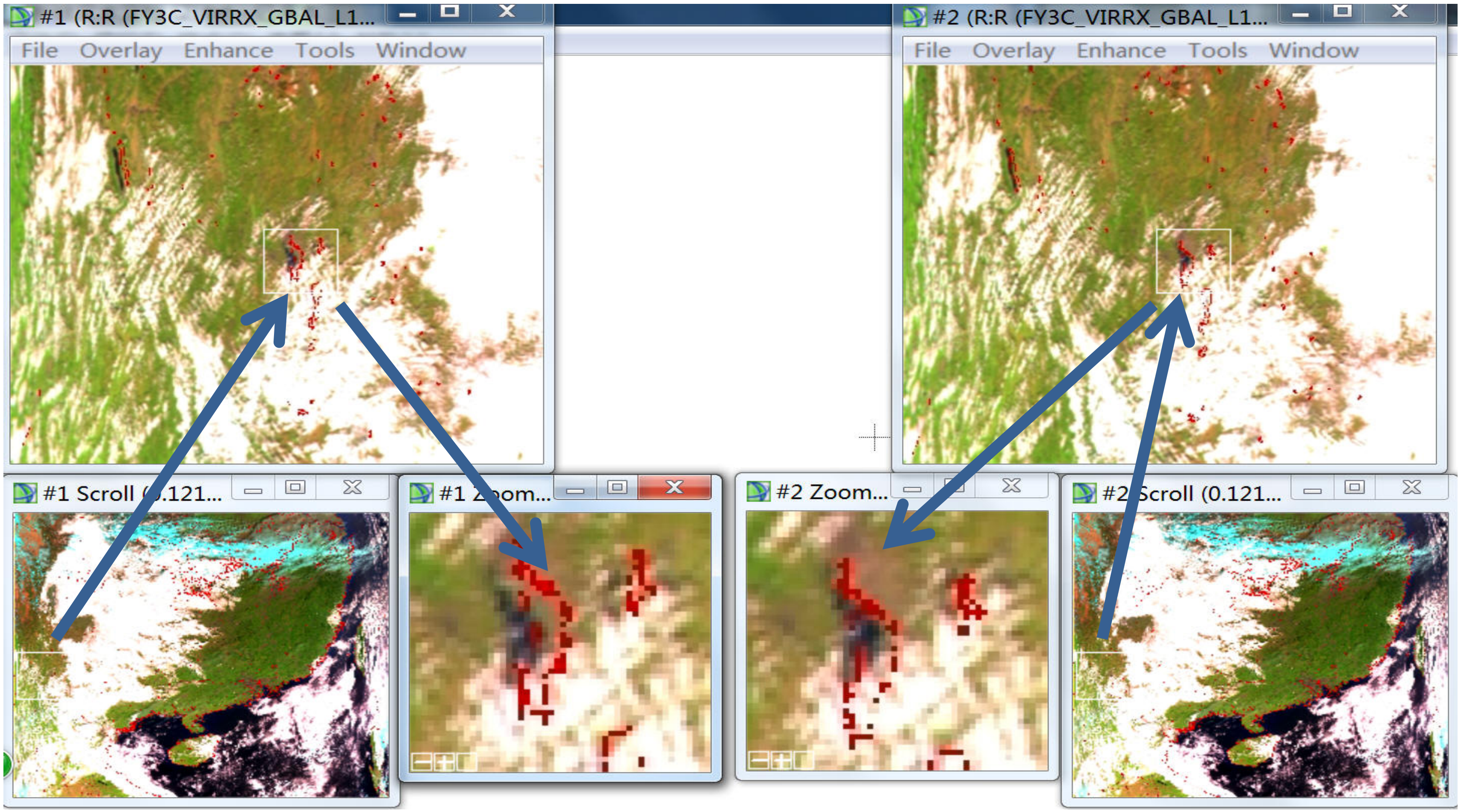


Fig.2 Coordinate used in Mis-alignment Parameters Adjustment Algorithm

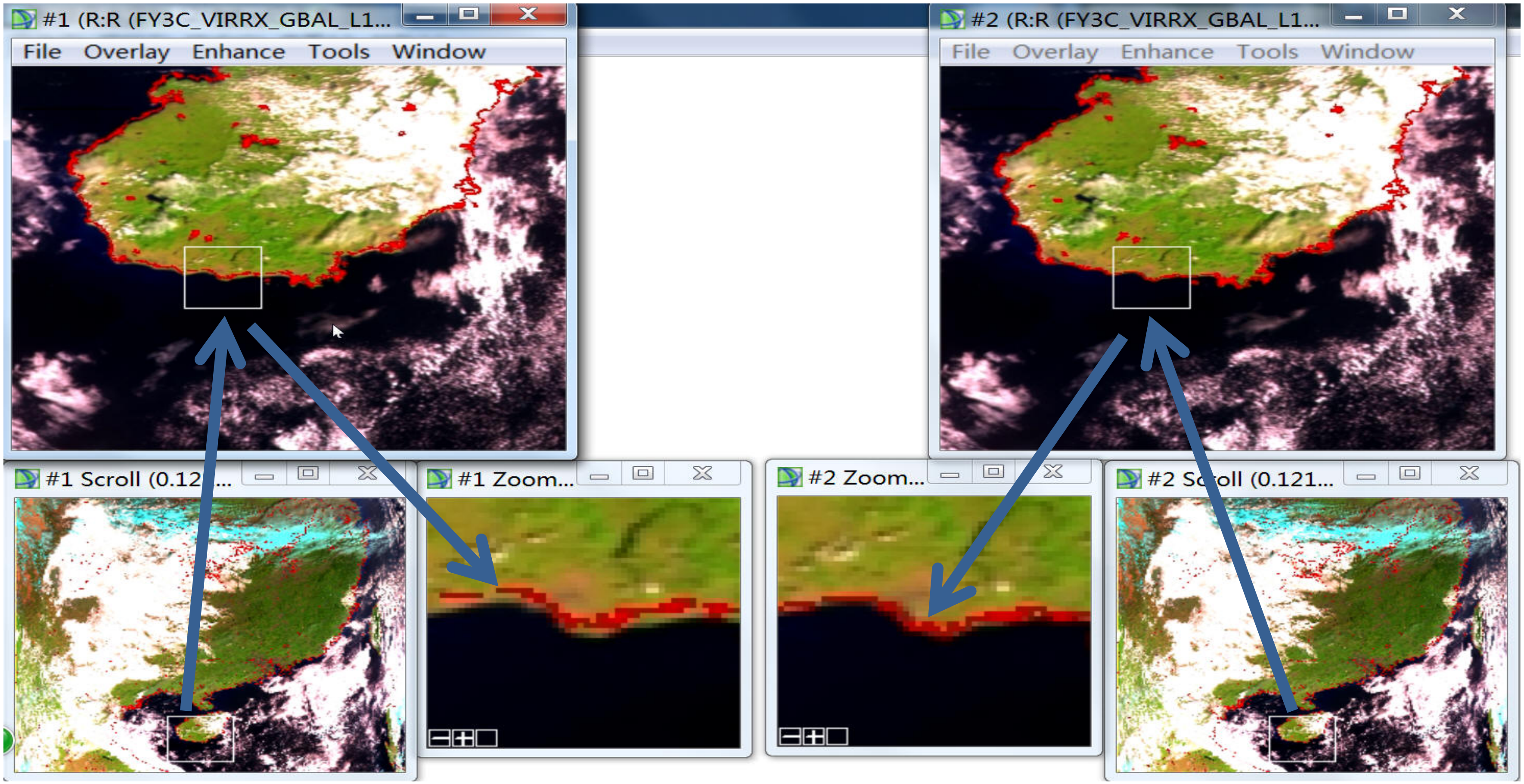
FY-3C Geolocation： 2 pixel → 1 pixel Image Edge



Before Update **After Update**

2013_1126_0300

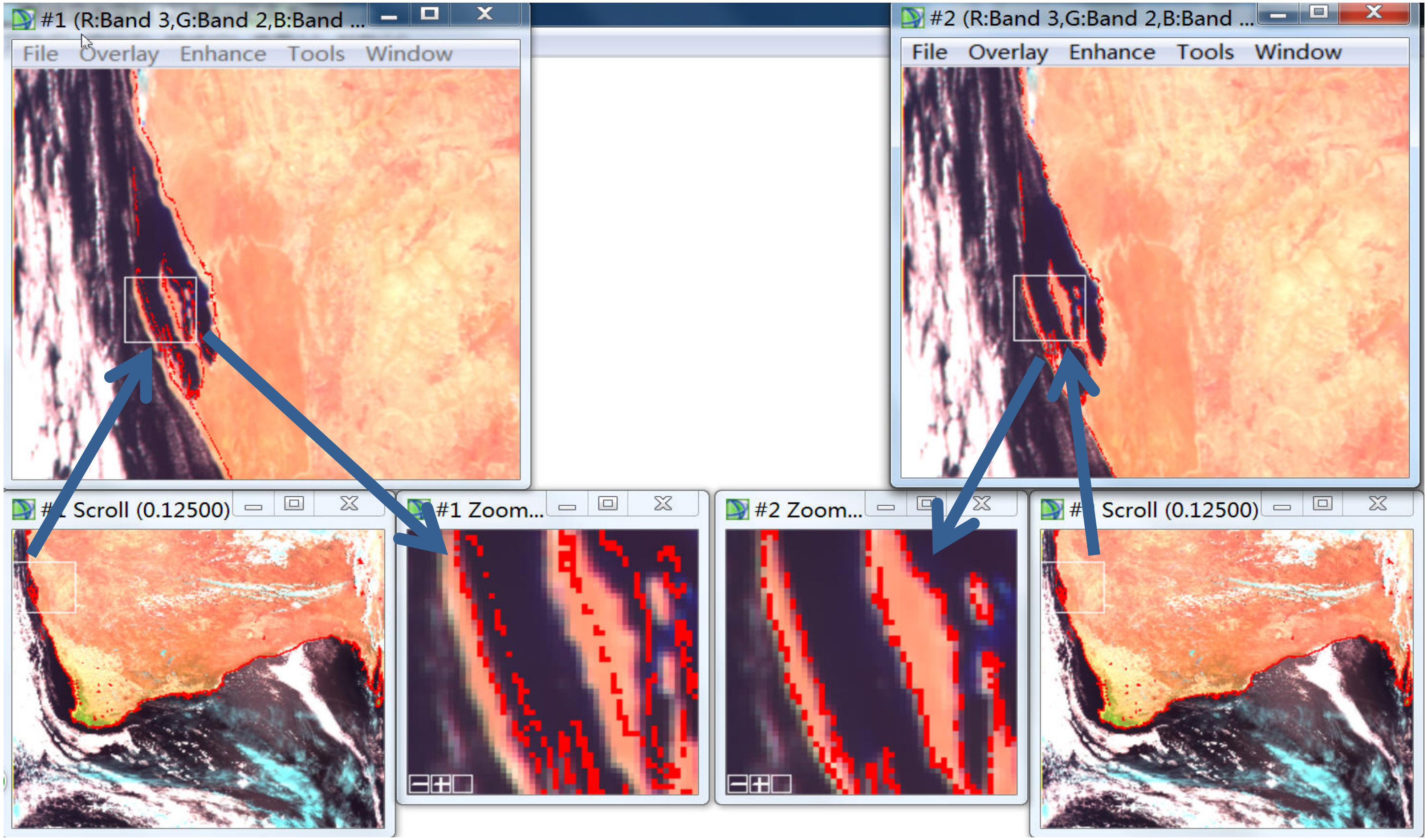
FY-3C Geolocation—sub pixel at Nadir



Before **After**

2013_1126_0300

FY-3C Geolocation： 3 pixel → 1 pixel   Image Edge



Before **After**

2013_1126_0135

FY-3C Geolocation Improve the Data Application Effect

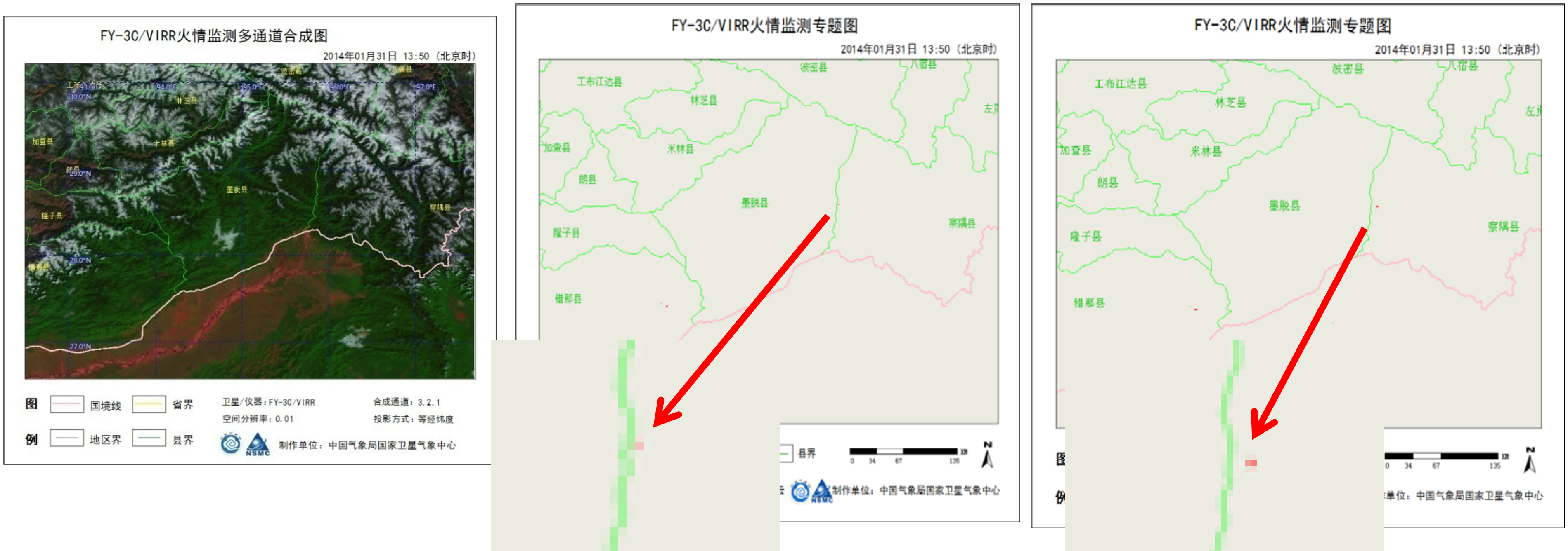


Fig.1 Fire Detection in Tibet on 31st Jan. 2014

Position: Motuo County/Chayu County → Chayu County

Fire Type: Forest → Forest&&Grassland

FY-3C DEM Correction

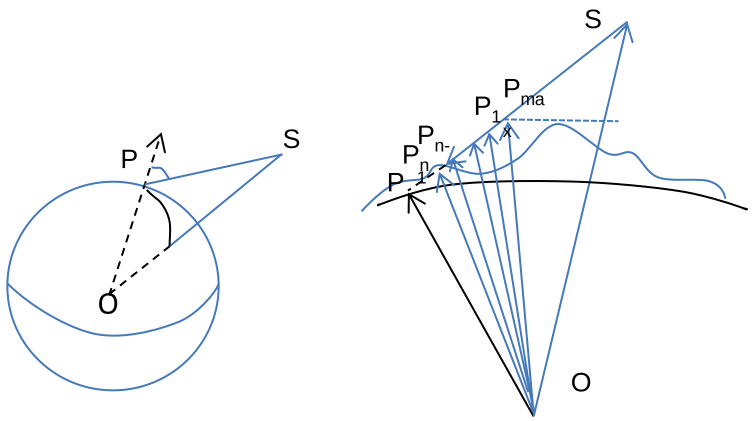
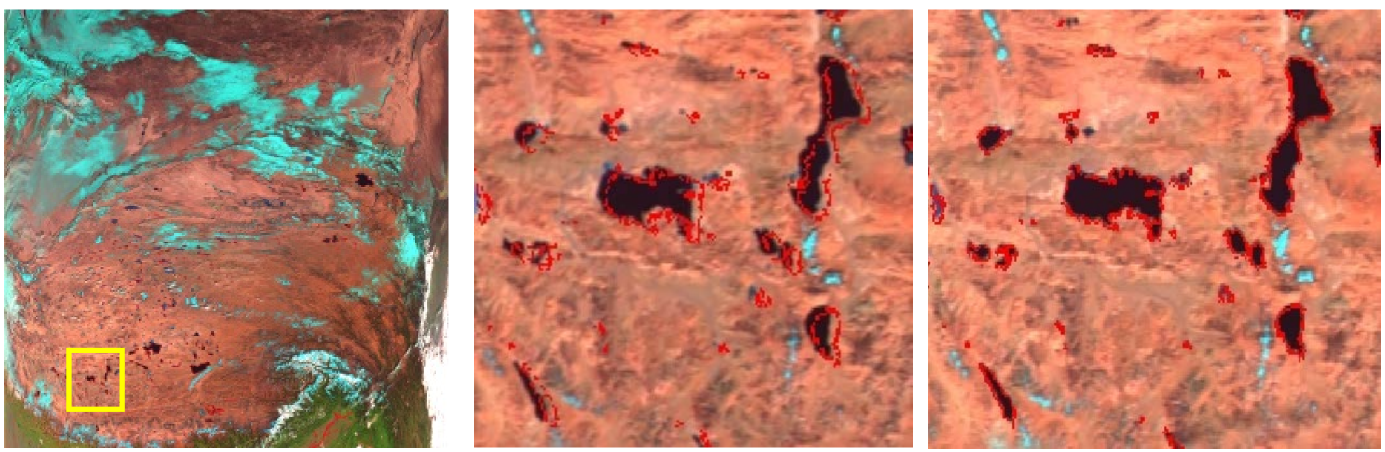


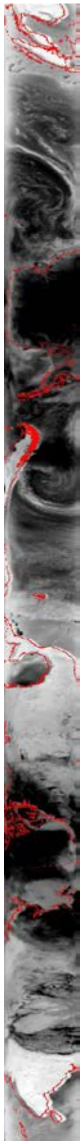
Fig.1 Geometry of the terrain correction algorithm

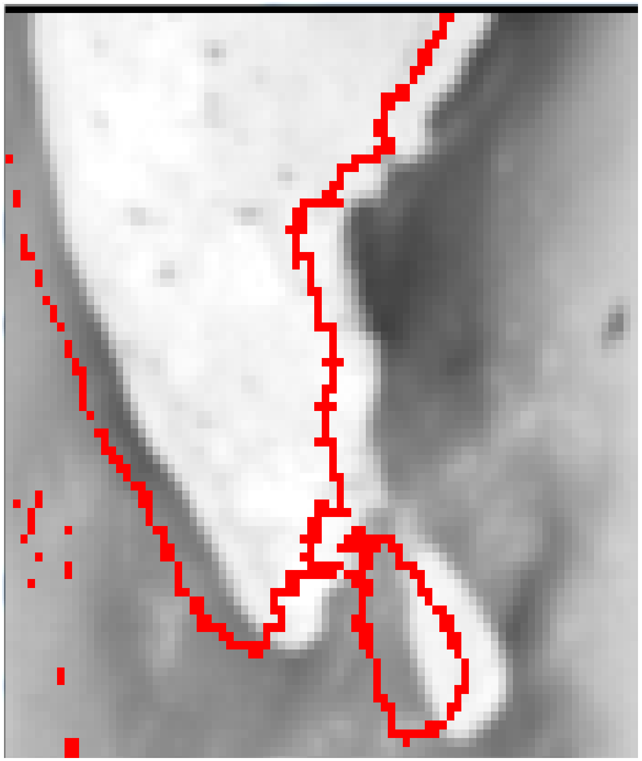


(a) Marked part is enlarged in right. (b)Based on ellipsoid (c) After terrain correction

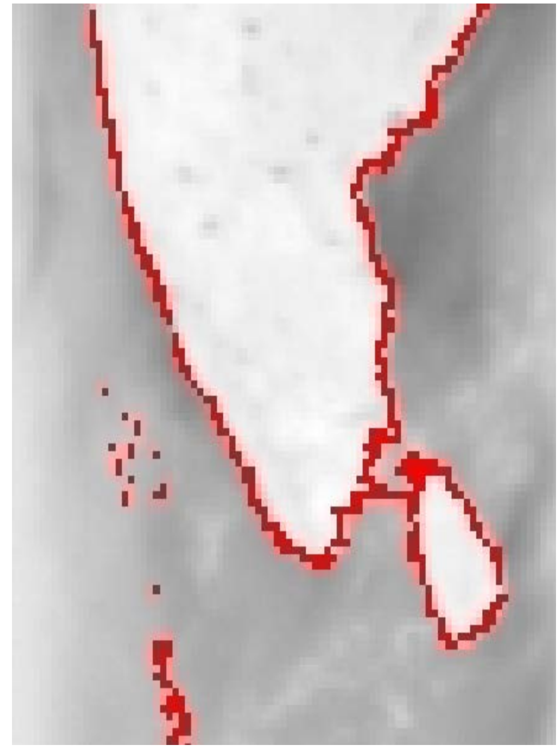
Fig.2 Geolocation of VIRR_20141115_0435 based on ellipsoid and topography

FY-3C MWHS/MWTS Pointing Correction At Launch

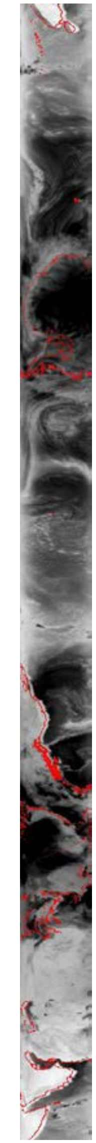




(a) Before

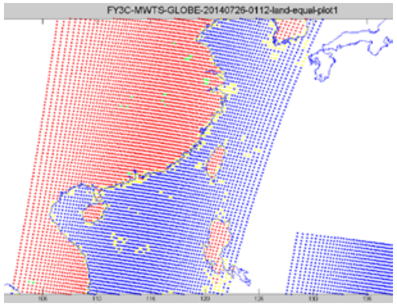


(b) After

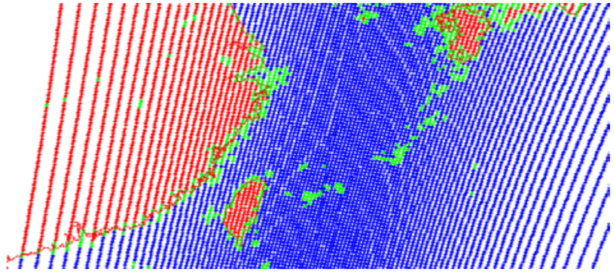


At launch, we found that FY-3C MWHS /MWTS pointing direction error occurred. By on-orbit software correction, MWHS pointing goes on well now. But, MWTS has some error due to the mechanic rotating system on the payload.

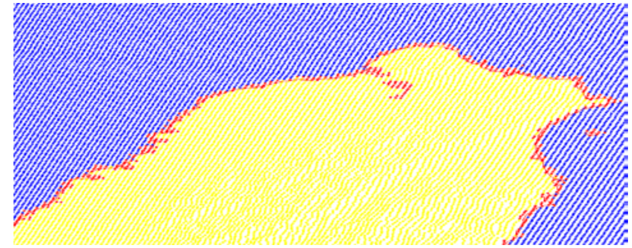
All 9 payloads data geolocation are in operation in the CMA ground system.



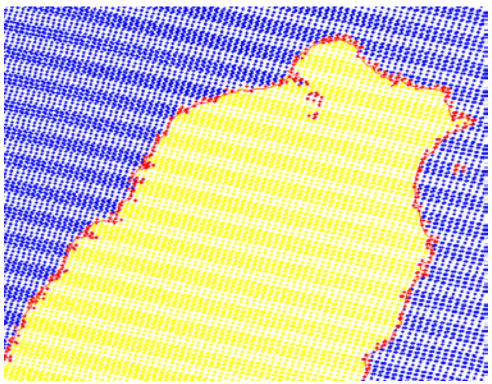
MWTS



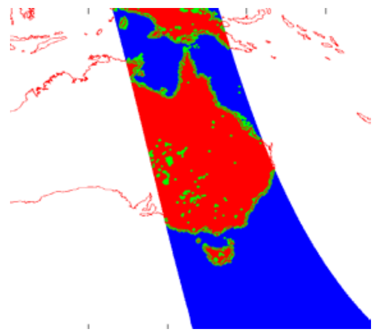
MWHS



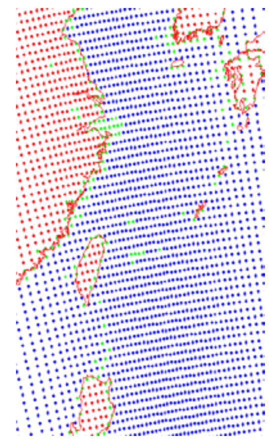
VIRR



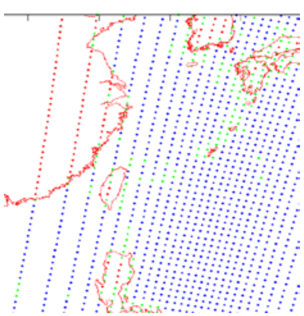
MERSI



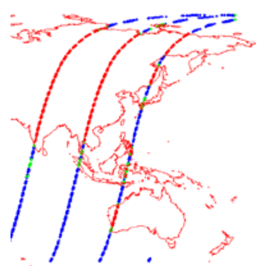
MWRI



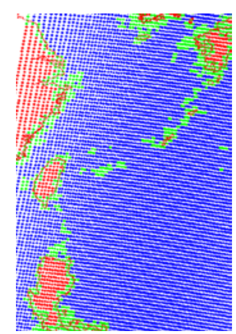
IRAS



TOU



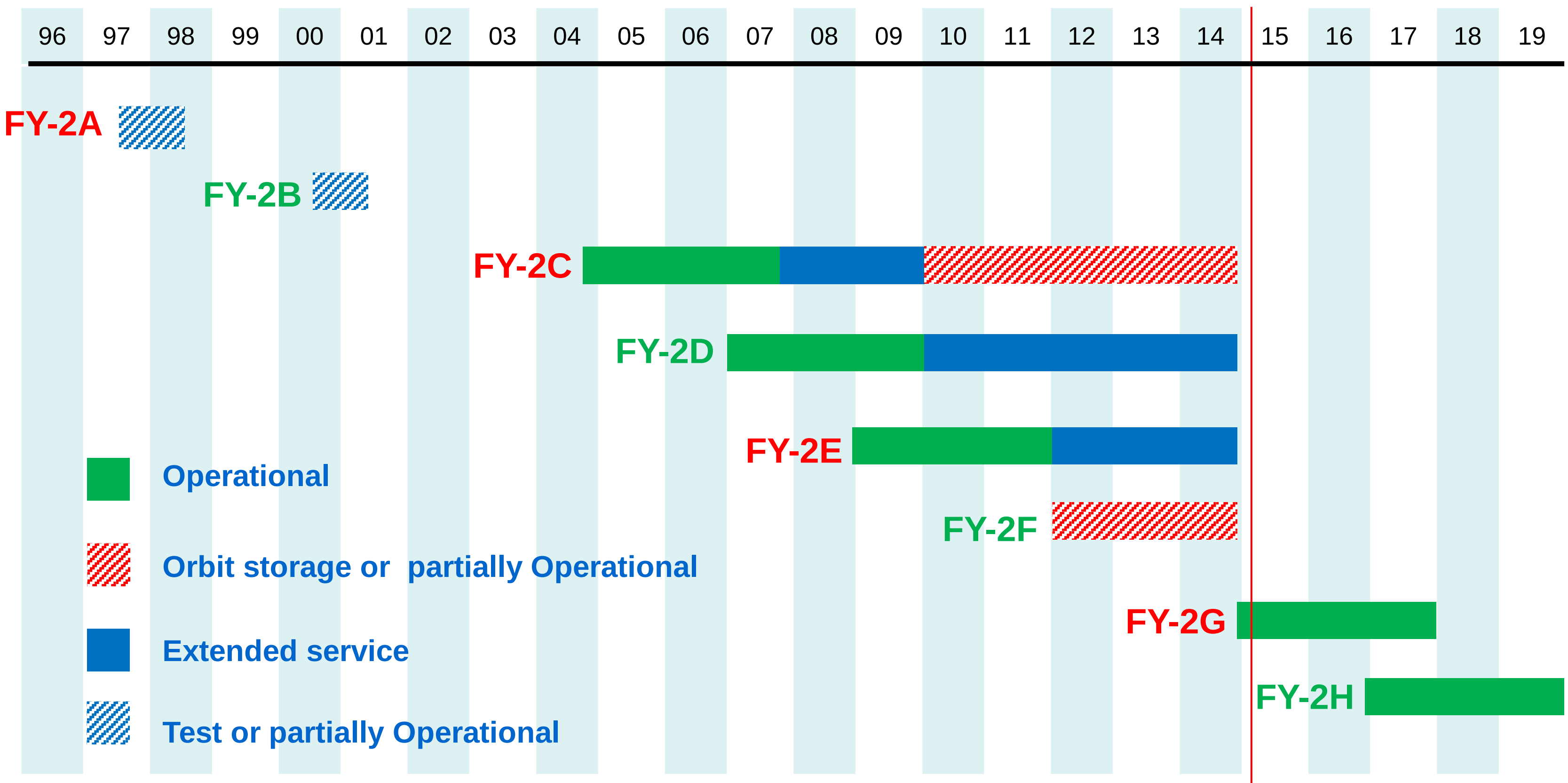
SBUS



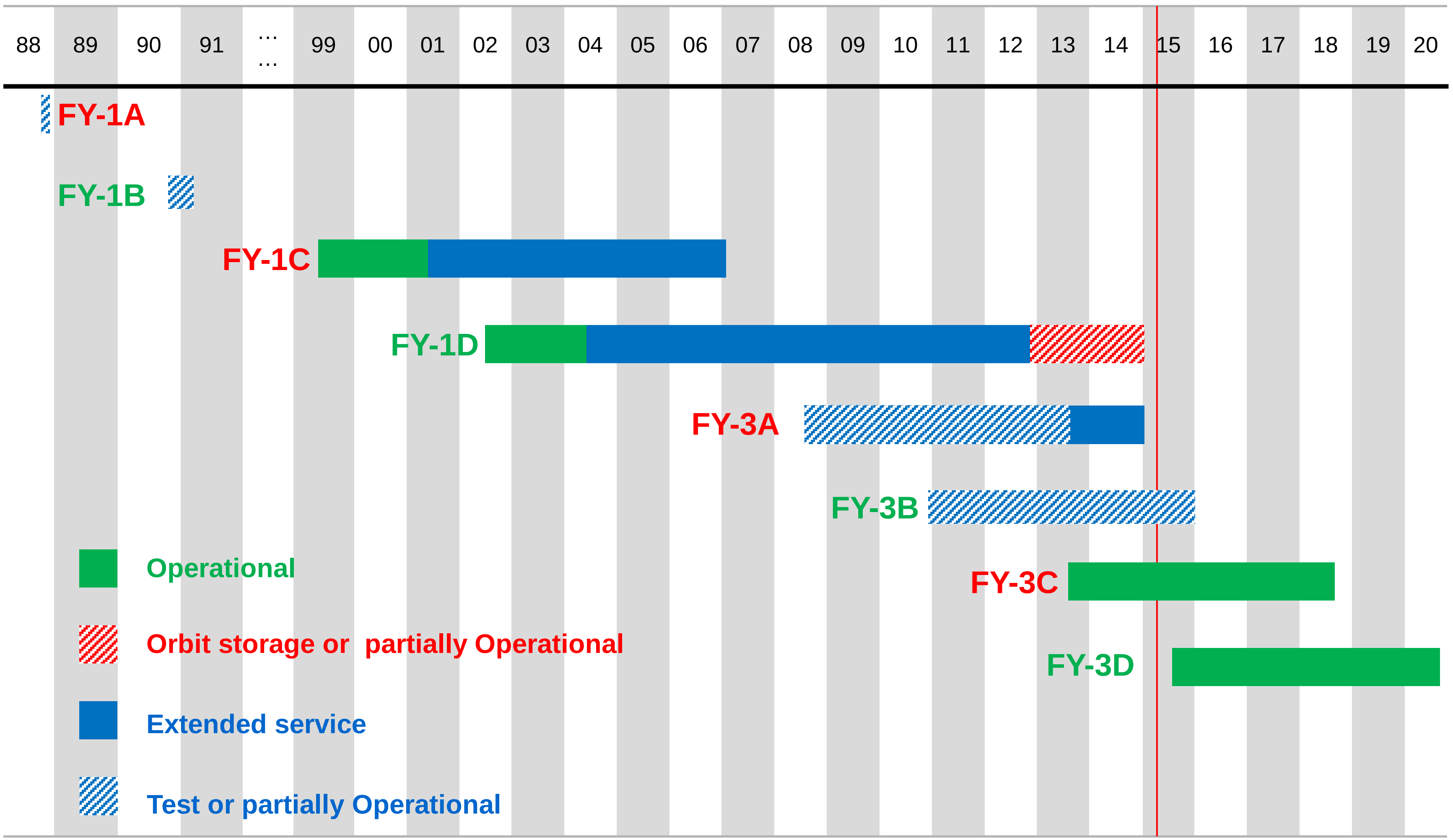
ERM

FengYun Satellite Program and its Future Plan

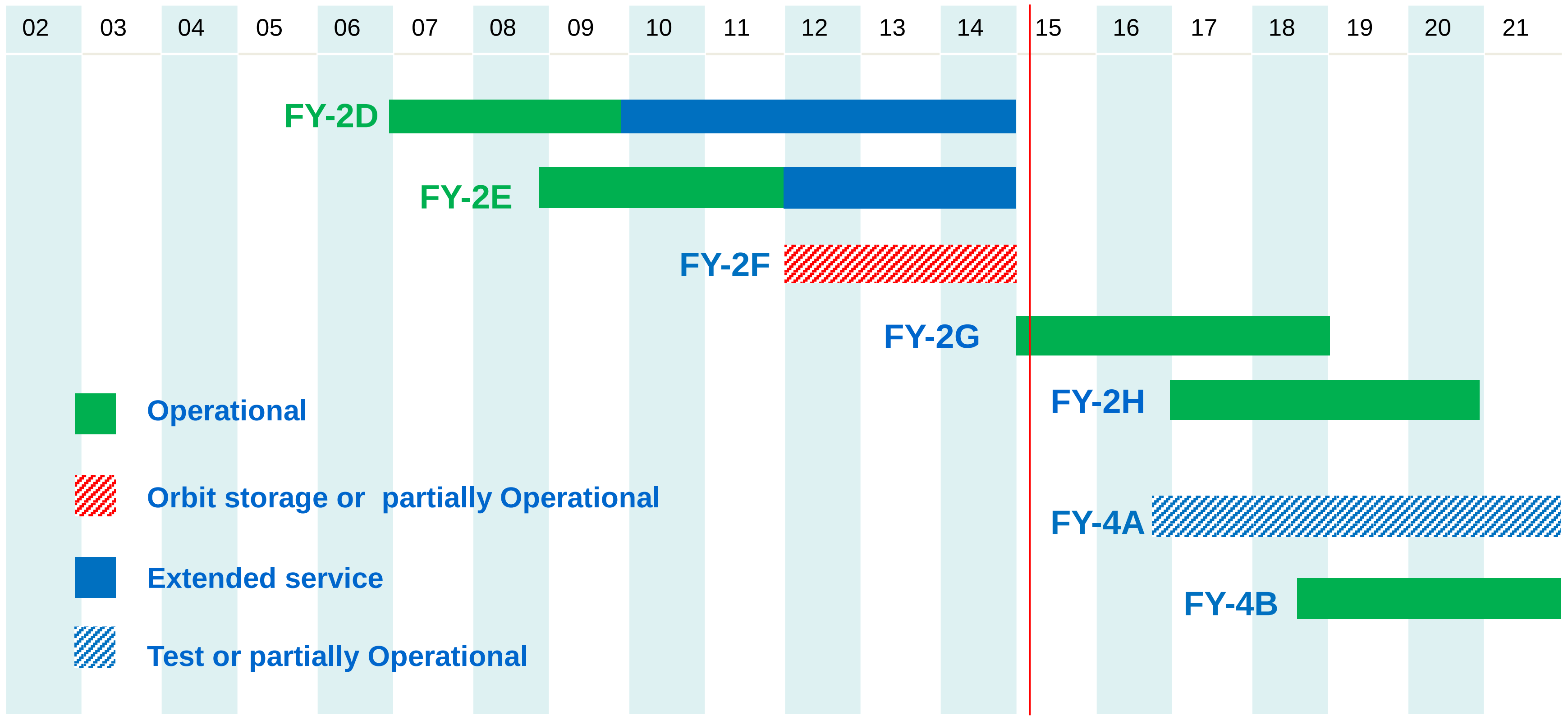
CURRENT CMA GEO SATELLITES



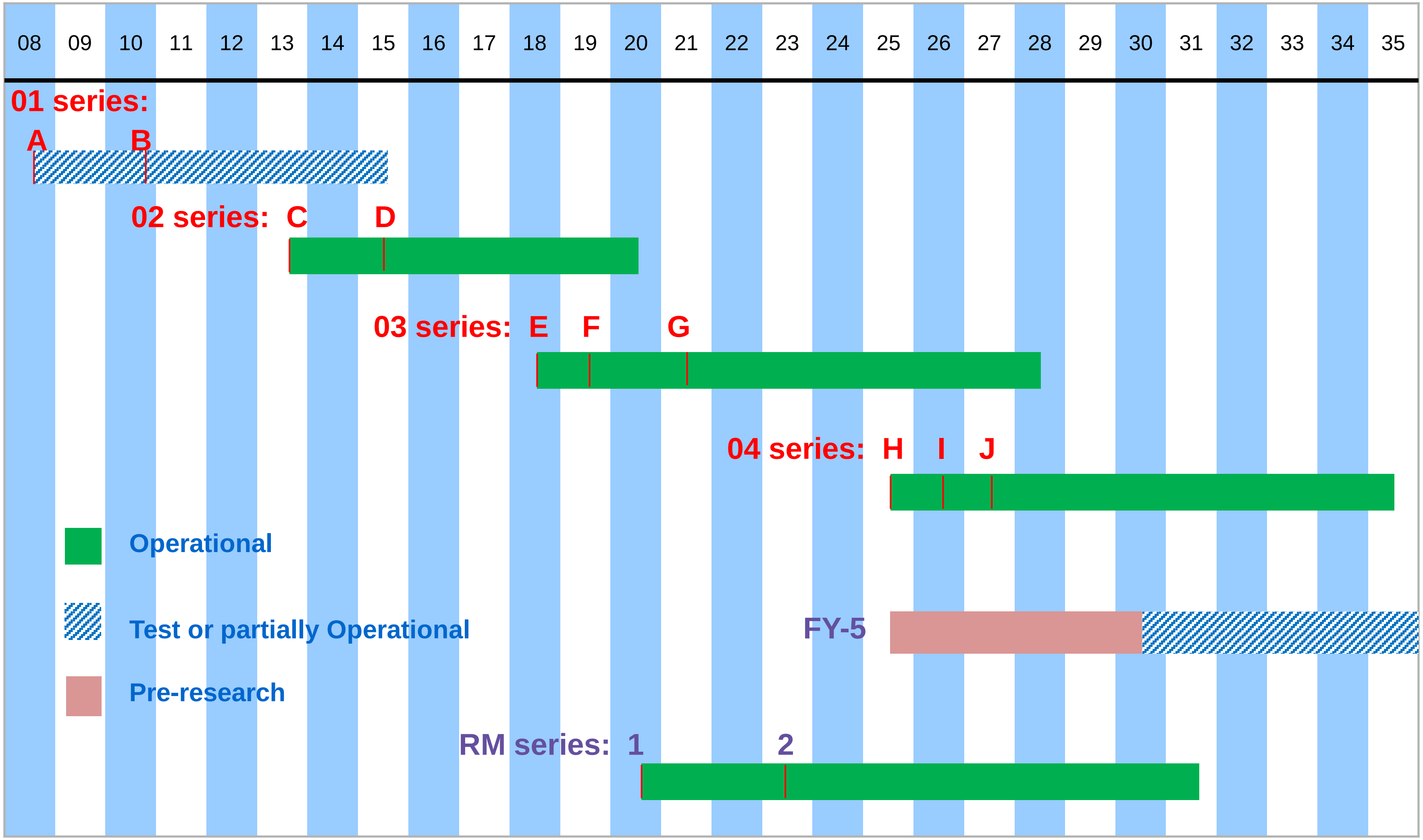
CURRENT CMA LEO SATELLITES



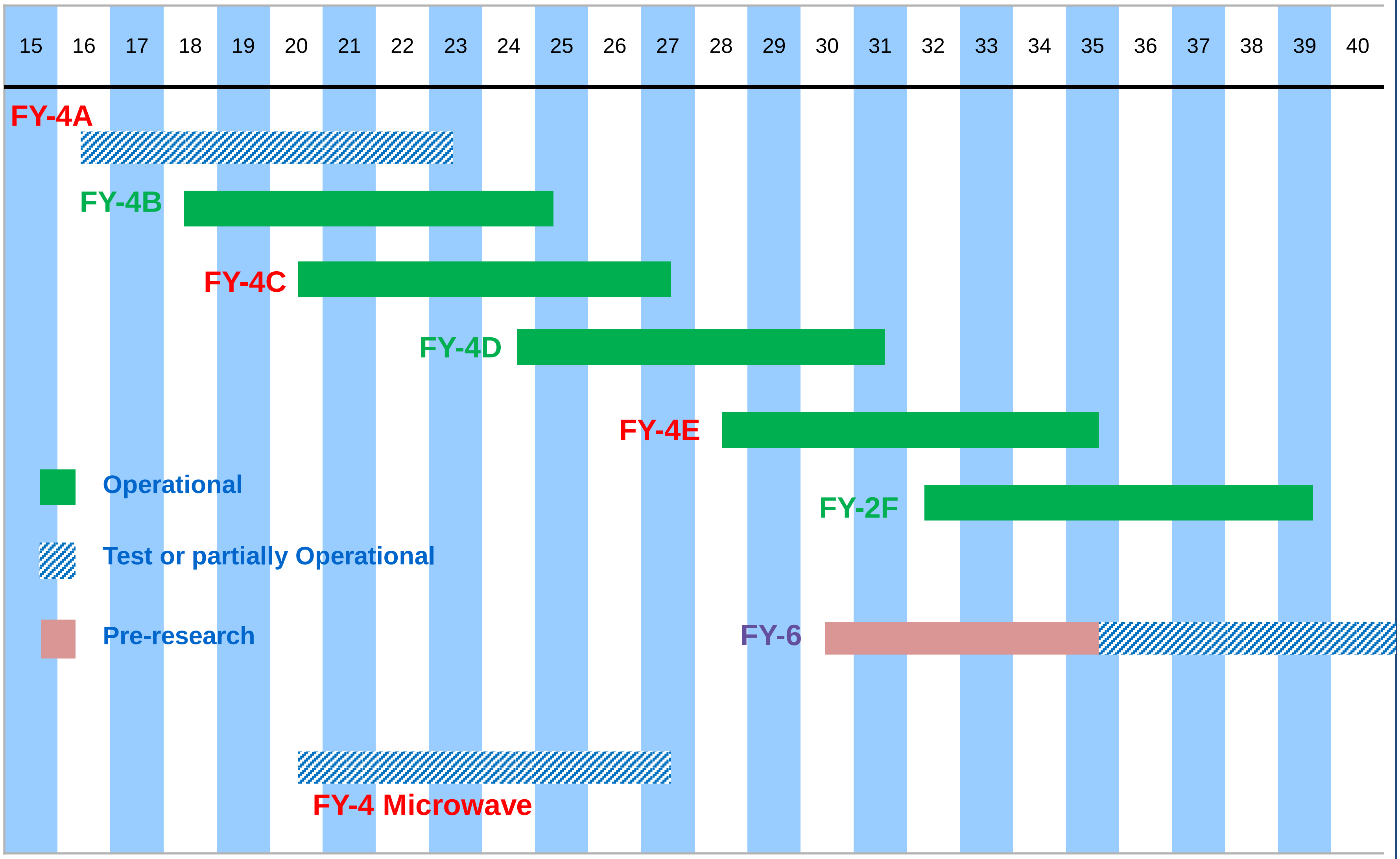
CMA GEO SATELLITES FROM FY-2 TO FY-4



CMA LEO SATELLITES FROM FY-3 TO FY-5



CMA GEO SATELLITES FROM FY-4 TO FY-6



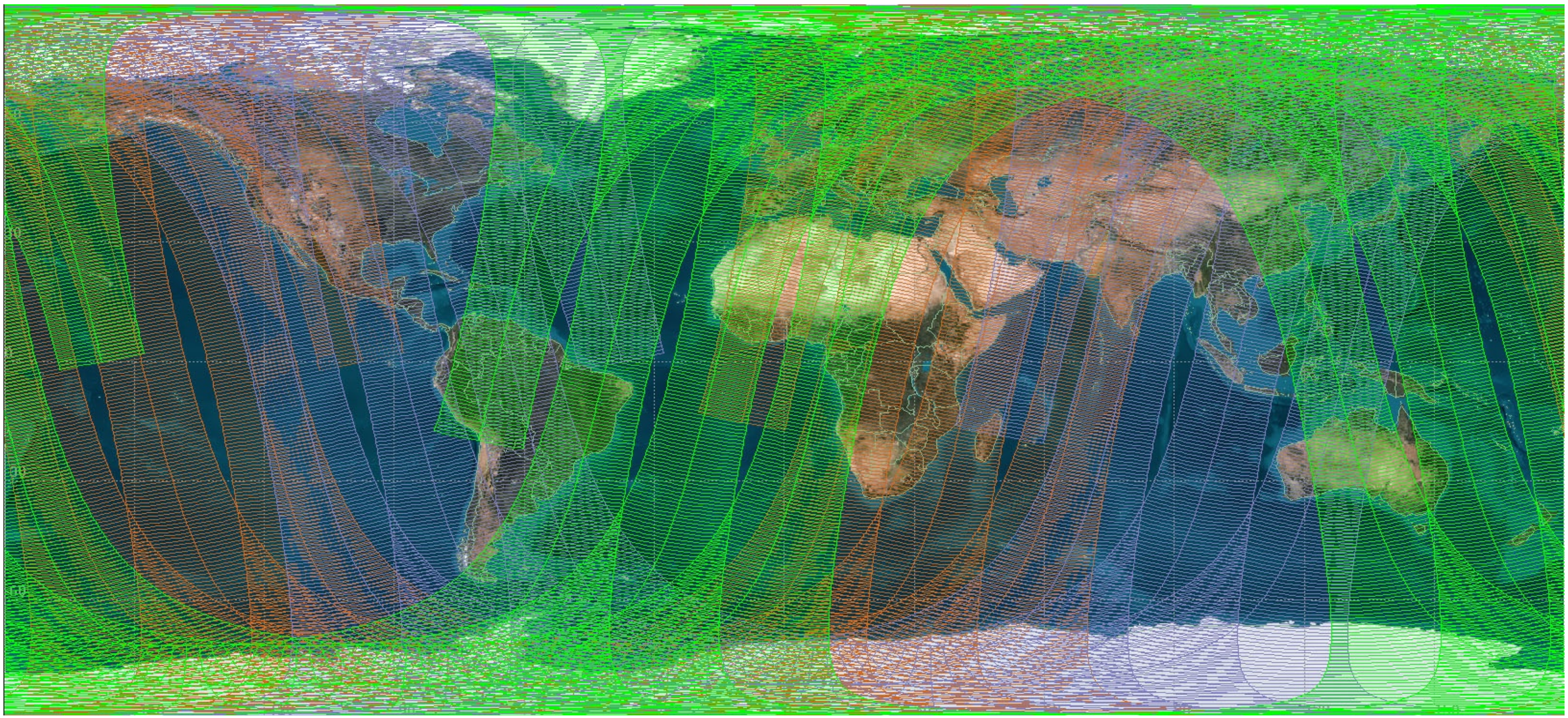
FY-3E(Early Morning Orbit) is coming……

FY-3 OPERATIONAL SATELLITE INSTRUMENTS	FY-3C	FY-3D	FY-3E
MERSI – Medium Resolution Spectral Imager (I, II)	√(I)	√(II)	√(II)
MWTS – Microwave Temperature Sounder (II)	√	√	√
MWHS – Microwave Humidity Sounder (II)	√	√	√
MWRI – Microwave Radiation Imager	√	√	
WindRAD - Wind Radar			√
GAS - Greenhouse Gases Absorption Spectrometer		√	
HIRAS – Hyper spectral Infrared Atmospheric Sounder		√	√
OMS – Ozone Mapping Spectrometer			√
GNOS – GNSS Occultation Sounder	√	√	√
ERM – Earth Radiation Measurement (I, II)	√(I)		√(II)
SIM – Solar irritation Monitor (I, II)	√(I)		√(II)
SES – Space Environment Suite	√	√	√
IRAS – Infrared Atmospheric Sounder	√		
VIRR – visible and Infrared Radiometer	√		
SBUS – Solar Backscattered Ultraviolet Sounder	√		
TOU – Total Ozone Unit	√		

↑ 2016 ↑ 2018

Orbit Option: FY-3 Early Morning + NPP + Metop

Recognizing that global even distribution of sounding data is of great significance for the 6 hour NWP assimilation window, one approach is to constitute a three orbital fleet including **Metop** **(Mid.** Morning) **+ NPP** **(Afternoon)** **+ FY-3** **(Early Morning).**

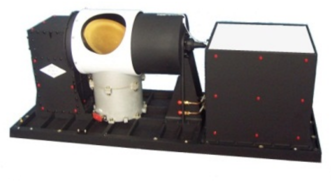


FY-3 Early Morning 6:00 AM

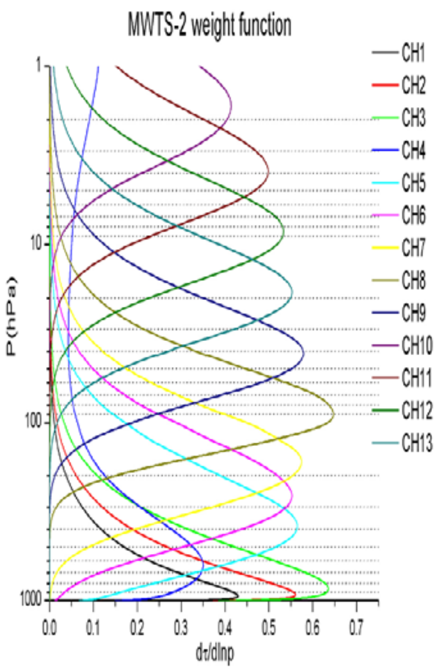
Metop-A 9:30 AM

NPP 13:30 PM

MWTS II



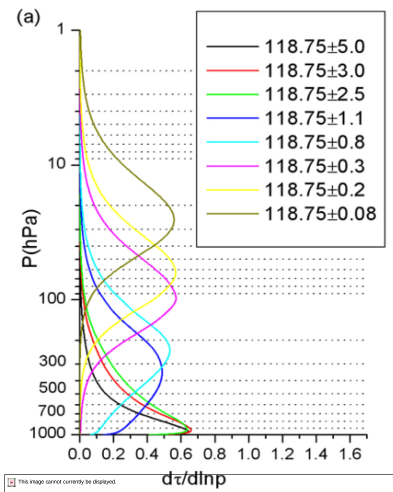
Parameter	Specification
Scan Angle	±49.5°
Pixels Per Scan Line	90
Quantization	13 bits



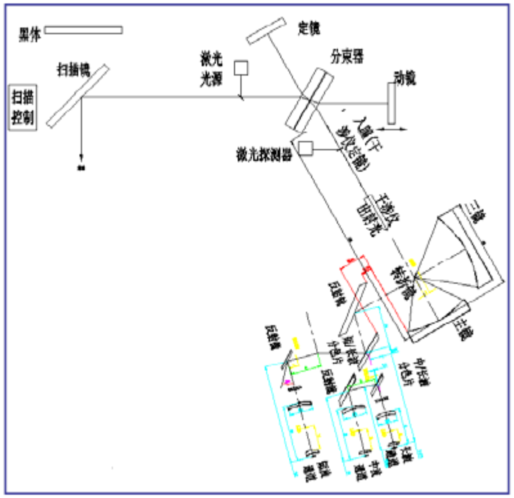
Ch No.	Central Frequency （GHz）	3dB Bandwidth （MHz）	NEΔT （K）	Main Beam Eff.	Dynamic Range （K）	Cal. Acc. （K）	Purpose
1	50. 3	180	1. 20	>90%	3～340	1. 5	Surface Emiss.
2	51. 76	400	0. 75	>90%	3～340	1. 5	Atmospheric Temperature Profile
3	52. 8	400	0. 75	>90%	3～340	1. 5	
4	53. 596	400	0. 75	>90%	3～340	1. 5	
5	54. 40	400	0. 75	>90%	3～340	1. 5	
6	54. 94	400	0. 75	>90%	3～340	1. 5	
7	55. 50	330	0. 75	>90%	3～340	1. 5	
8	57. 290344(fo)	330	0. 75	>90%	3～340	1. 5	
9	fo±0. 217	78	1. 20	>90%	3～340	1. 5	
10	fo±0. 3222±0. 048	36	1. 20	>90%	3～340	1. 5	
11	fo±0. 3222±0. 022	16	1. 70	>90%	3～340	1. 5	
12	fo±0. 3222±0. 010	8	2. 40	>90%	3～340	1. 5	
13	fo±0. 3222±0. 0045	3	3. 60	>90%	3～340	1. 5	

MWHS II

Parameter	Specification
Scan Angle	±53.35°
Pixels Per Scan Line	98
Quantization	14 bits



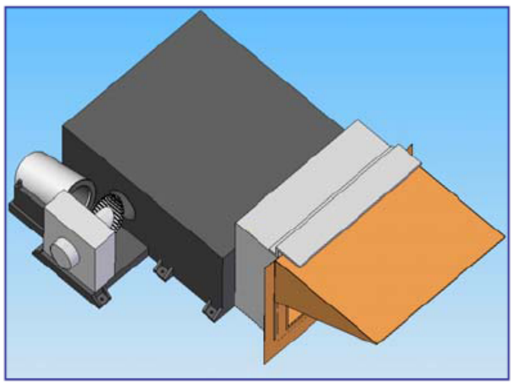
Ch No.	Central Frequency (GHz)	Polarization	Bandwidth (MHz)	Freq. Stability (MHz)	Dynamic Range (K)	NEΔT (K)	Cal. Acc. (K)	Main Beam Width	Main Beam Eff.	Purpose
1	89.0	V	1500	50	3—340	1.0	1.3	2.0°	>92%	Surface and Precipitation
2	118.75±0.08	H	20	30	3—340	3.6	2.0	2.0°	>92%	Atmospheric Temperature Profile
3	118.75±0.2	H	100	30	3—340	2.0	2.0	2.0°	>92%	
4	118.75±0.3	H	165	30	3—340	1.6	2.0	2.0°	>92%	
5	118.75±0.8	H	200	30	3—340	1.6	2.0	2.0°	>92%	
6	118.75±1.1	H	200	30	3—340	1.6	2.0	2.0°	>92%	
7	118.75±2.5	H	200	30	3—340	1.6	2.0	2.0°	>92%	
8	118.75±3.0	H	1000	30	3—340	1.0	2.0	2.0°	>92%	
9	118.75 ±5.0	H	2000	30	3—340	1.0	2.0	2.0°	>92%	
10	150.0	V	1500	50	3—340	1.0	1.3	1.1°	>95%	Surface and Precipitation
11	183.31±1	H	500	30	3—340	1.0	1.3	1.1°	>95%	Atmospheric Moisture Profile
12	183.31±1.8	H	700	30	3—340	1.0	1.3	1.1°	>95%	
13	183.31±3	H	1000	30	3—340	1.0	1.3	1.1°	>95%	
14	183.31±4.5	H	2000	30	3—340	1.0	1.3	1.1°	>95%	
15	183.31±7	H	2000	30	3—340	1.0	1.3	1.1°	>95%	



HIRAS

Specification	LWIR Band	MWIR Band	SWIR Band
Spectral Range	650 – 1136 cm-1	1210 – 1750 cm-1	2155-2550 cm-1
Spectral Res	0.625 cm-1	1.25 cm-1	2.5 cm-1
NEΔT @250K	0.15~0.4K	0.1~0.7K	0.3~1.2K
pixes per scan line	58		
Scan Angle	±50.4° around nadir		
Spatial Res	1.1 degrees (16.0km) IFOV at arranged in 2×2 array		
Power/Mass	129watts/120kg		

3*3 arrays in FY-3E



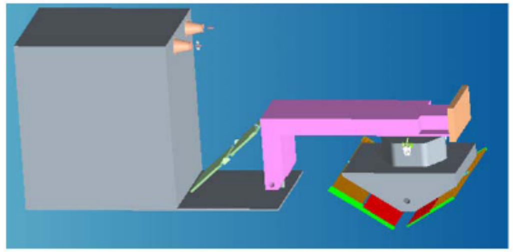
HIRAS/FY-3: Michelson interferometer

Aims: global temperature and moisture sounding from the infrared spectrum from 650 to 2550 cm−1

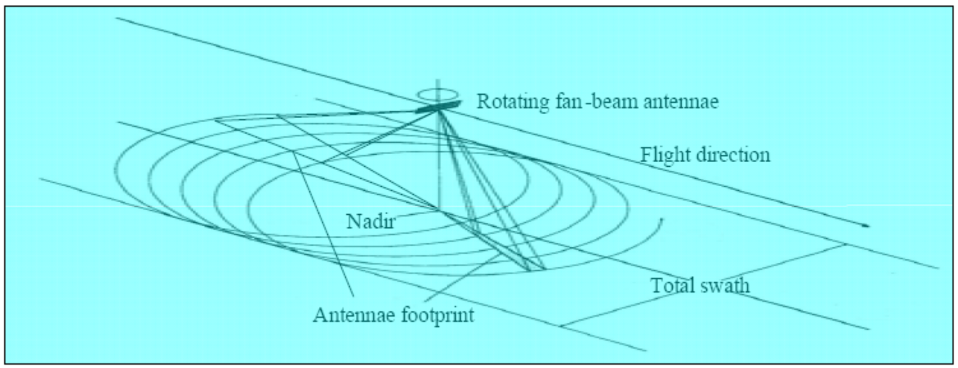
1) **retrieving atmospheric temperature and humidity profiles with high accuracies for numerical weather prediction and climate research at high vertical resolution.**
2) **Trace gases to be derived from HIRAS include ozone columnar amounts in deep layers and columnar amounts of carbon monoxide, nitrous oxide, methane, and carbon dioxide.**
3) **Cloud parameters .**

WindRAD

The Wind Radar monitors Global ocean surface wind field (OSWF) from space. The wind radar will measure the radar backscattering of sea surface from different azimuth and then retrieve wind vector with the geophysical model function (GMF). The OSWF data will significantly contribute to improve weather forecast, especially numerical model prediction of typhoon tracks and landfalls.

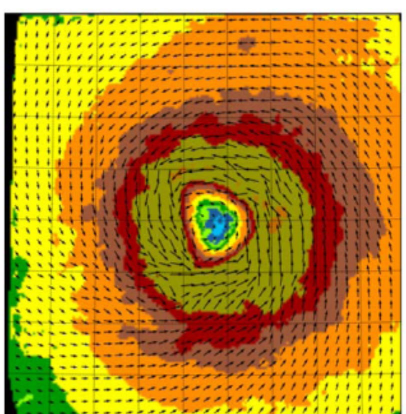


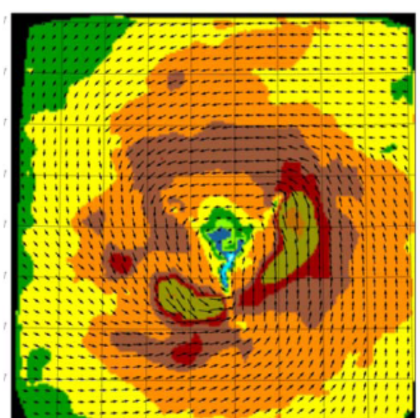
Wind Radar



Measurement geometry of Wind Radar

The four antennae (two polarization of each frequency) of Wind Radar rotate slowly around the vertical axis of spin platform, and each pixel within the swath will be illuminated from more azimuth directions than the existing spaceborne sactterometers due to the low rotation rate .





Wave band		C	Ku
Centre frequency		5.3GHz	13.256GHz
Polarization		HH,VV	HH,VV
Spatial resolution	azimuth direction	≈25 km	≈10 km
	range direction	≤ 10 km	≤ 5 km
Swath width		> 1200 km	
Incidence angle		36° ~ 45°	37° ~ 43°
Peak Gain		31 dBi	37.5 dBi
Transmitted power		124 W	141 W
Rotation rate		0.4 ~ 0.7 rad/s	
Radiometric accuracy		1dB (≤ 5m/s); 0.5dB (others)	
Wind speed range		3 ~ 50 m/s	
Wind speed accuracy		1.5 m/s (≤ 20m/s); 10% (others)	
Wind speed range		0 ~ 360°	
Wind direction accuracy		< 20°	

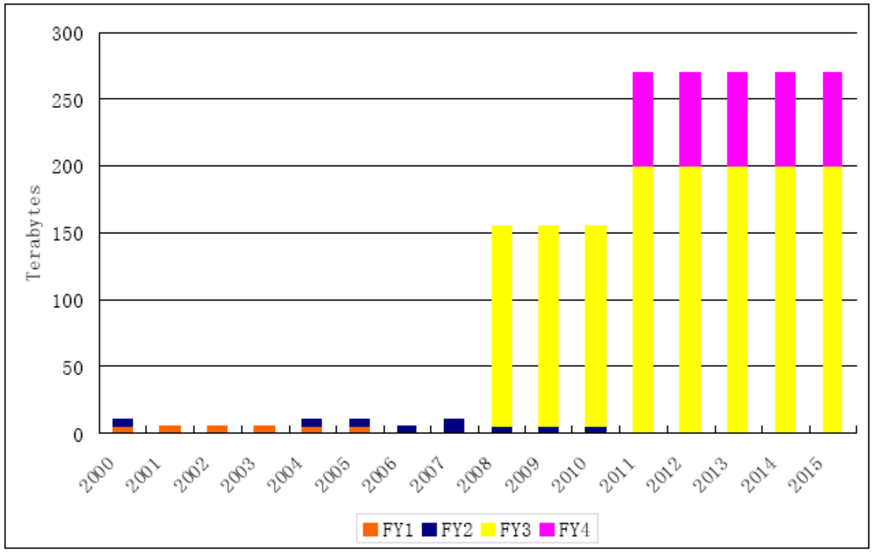
Expected performance of the Wind Radar

- Better spatial resolution than the current spaceborne scatterometers;
- High wind retrieval capability ;
- Nearly all-weather capability .

Data Service and Sharing — Hot line: 4006-121-701

http://satellite.cma.gov.cn

1. **Web-based service(registered user)**
2. **FTP Push(important user)**
3. **FTP Pull(registered user)**
4. **Manual Service(emergency)**
5. **Fengyun Cast(registered user)**
6. **DB Users(register user)**



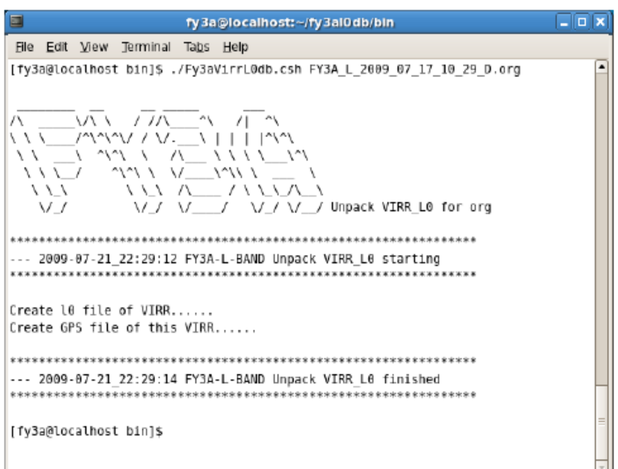
DB Users – FY-3 International Pre-processing Packages

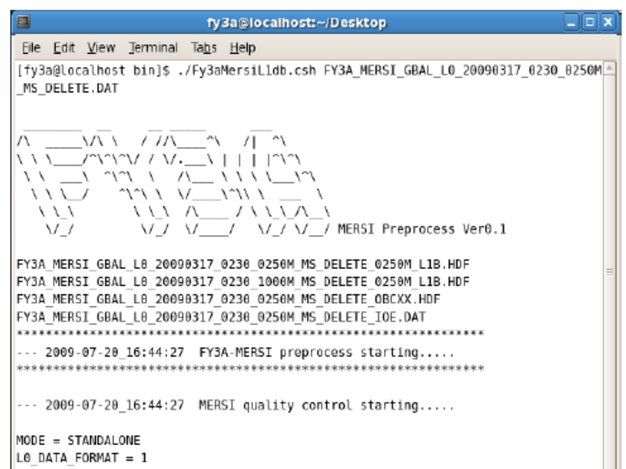
No Multi-thread Until now.

- 5 Instruments available
  - ✓MERSI, VIRR, MWTS, MWHT, IRAS (not for FY-3A)
- Hardware recommended
  - ✓RAM: >2.0GB
  - ✓CPU: Intel Pentium Duo Core processor (>3.0Ghz)
  - ✓Hard disk: >200GB
- Operating system tested
  - ✓RedHat Fedora Linux 6.0/8.0/10.0
- 2 Software packages released
  - ✓FY3L0pp: unpack raw data in both X/L bands to generate level-0 data from the 5 instruments
  - ✓FY3L1pp: processes level-0 data to generate corresponding level-1 data respectively.

Latest Update

MEPGPS	20140403GEO_parameters_MERSI_F3C.cfg	20140410
VIPGPS	20140627GEO_parameters_VIRR_F3C.cfg	20140411
IRPGPS	20140320GEO_parameters_IRAS_F3C.cfg	20140410
WTPGPS	20150114GEO_parameters_MWTS_F3C.cfg	20150114
WHPGPS	20140329GEO_parameters_MWHS_F3C.cfg	20140410





FY-3 International Processing Package

Reply to "Comparision of FY-3 local processing software product and CMA products"(10th March, 2015):

1. MWHS Channel 15 data consistency. ----Have been solved. And the FY-3C LPP software will be updated via ftp site.

2. X-/L-band CADU format.----Have been solved. And the FY-3C LPP software will be updated via ftp site.

3. FY3-C are transmitted to Earth via left-hand polarised X-Band. ----Cannot use right-hand polarised x-band because of the similar orbit FY-3A data reception.

4. MERSI 250m channel data consistency.– VIS/NIR is identical between EARS and CMA. Maybe the data receive in Europe exists some problem in that scan line.

5. FY-3C LPP multi-thread handling.---- We will make it in the FY-3D/E/....

Conclusions

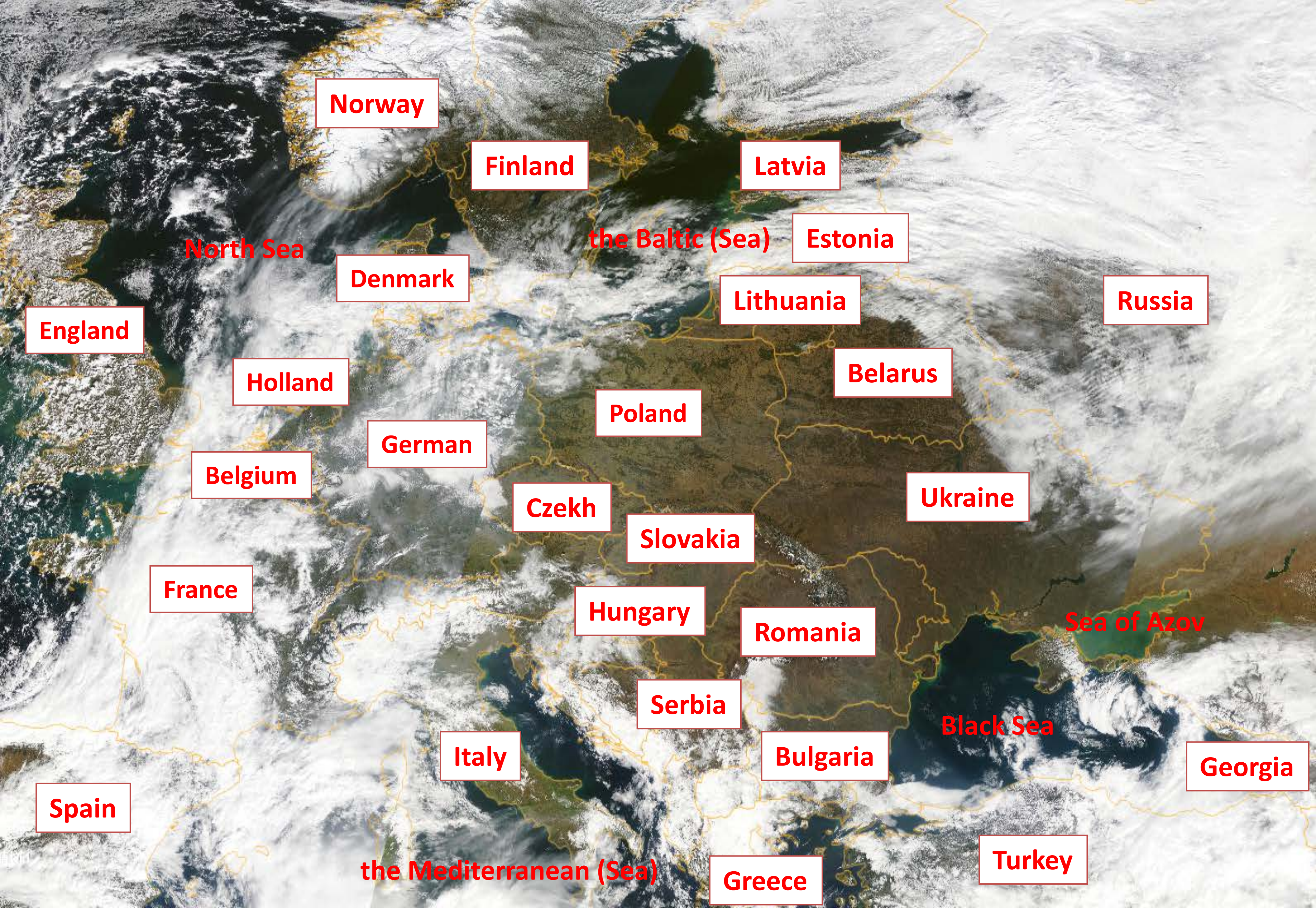
- FY-3C data geolocation are in operational in CMA ground system and has achieved 1-pixel accuracy.
- FY-3E (Early morning) is coming, which carries passive/active microwave intruments, high spectral infraed sounder and DNB Imager .
- Fengyun satellites can provide data services through various methods, including web service, FTP and Fengyun Cast.
- FY-3C LPP have been updated to resolve the recent problem. And we will enhance the notification information for the software update. Also, the testbed is needed for the comparison between FY-3LPP and CMA ground system.

Thank you for your attention!

Dr. Lei Yang, Professor

Chief Designer for FY-3/4 Geolocation and Registration

yangl@cma.gov.cn



FY-3C MERSI RGB Image(24th March, 2015)