

REPORT ON THE STATUS OF CURRENT AND FUTURE SATELLITE SYSTEMS

Executive summary

CMA operates FENG YUN geostationary and polar-orbiting satellite systems. The current sun-synchronous polar-orbiting FY fleet has 3 satellites, FY-3A/B/C. FY-3B/C provide X-band and L-band DB service with VIS, IR, and microwave imagery, IR and microwave sounding data. Other functions include ozone detection and space environment monitoring. The paper informs the CGMS that FY-3D will be launched the end of 2016, the X-band transmission contains full information of instruments measurement on board. Future plan includes FY-3E/F/G/RM. In particular, the FY-3E (2018) is being developed for early morning orbit; FY-3RM (2020) is planned for measuring rainfalls with Ku/Ka band active radar.

The current FENG YUN geostationary constellation has four satellites in orbit: FY-2D/E/F/G. FY-2E(86.5 °E) and FY-2G(105 °E) routinely transmit S-VISSR imagery; FY-2F(112 °E) takes sector scanning at requests; FY-2D(123.5 °E) is retired. CMA is developing FY-4, it's a three-axis stabilized platform to carry the Advanced Geo Radiation Imager, the Geo Interferometric Infrared Sounder, the Lightning Mapping Imager, and the Space Weather Monitor. FY-4 transmit LRIT/HRIT format data, provide DCS. Preparation for launching FY-4 is fist targeted at the end of 2016.

Action/Recommendation proposed: None

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1 INTRODUCTION

The CMA Feng Yun Meteorological Satellite Programme includes both geostationary and polar orbiting satellite missions. Feng Yun satellites, or FY in acronym, take place in series. The odd number series is the polar-orbiting series, the even number series the geostationary. The capital letter in the serial number refers to the seat of this particular satellite in the launching sequence.

2 CURRENT SATELLITE SYSTEMS

2.1 Status of current GEO satellite systems

CMA is operating the FY-2 GEO system. FY-2x is a spin-stabilized platform at rotation velocity 100 rpm. The main payload is a 5-channel Visible and Infrared Spin Scan Radiometer (VISSR), which takes hourly full disk imagery of the earth in VIS, IR, and water vapour channels.

The primary operational observation position of FY-2 satellites is 105 °E, the secondary position is 86.5 °E. The current FY-2 constellation consists 4 satellites, namely FY-2D/E/F/G.

Table 1 – Current Feng Yun Geostationary Satellites
(as of May 15, 2016)

Sector	Satellites currently in Orbit (+type) P: Pre-operational Op: operational B: Back-up L: Limited availability	Operator	Location	Launch date	Status
West-Pacific (108°E-180°E)	FY-2D(L)	CMA	123.5 °E	15 Nov 2006	Retired/ 5 channel VISSR, DCS, SEM
	FY-2F(P)	CMA	112 °E	13 Jan 2013	Orbital storage/ 5 channel VISSR, DCS, SEM
Indian Ocean(36°E-108°E)	FY-2G(Op)	CMA	105 °E	31 Dec 2014	5 channel S-VISSR, DCS, SEM
	FY-2E(Op)	CMA	86.5 °E	23 Dec 2008	5 channel S-VISSR, DCS, SEM

2.1.1 Mission objectives, payload/instruments

Primary objectives of FY-2 mission:

- Continuously observing to obtain the earth imagery in visible, infrared spectral ranges, from which sea surface temperature, cloud parameters, and wind vectors can be derived.
- Operating the Data Collection System (DCS) to collect and transmit data from domestic and overseas data platforms (DCPs).
- Broadcasting data in HRIT/LRIT format, and
- Monitoring space environment.

FY-2 payloads:

- **S-VISSR(Stretched Visible and Infrared Spin Scan Radiometer)** – The version for FY-2A/B had three VIS/IR channels (0.5-1.05 μ m, 6.3-7.6 μ m, and 10.5-12.5 μ m), the improved version for FY-2C/D/E/F/G splits the IR channels into two and adds a 3.5-4.0 μ m channels. The resolution is slightly improved from 5.76km (IR) and 1.44km (VIS), to 5.0km (IR) and 1.25 (VIS). The image cycle is 30 min.
- **Data Collection Service (DCS)** – Main feature: two uplink bands, frequencies 402.0-402.1MHz for international DCPs (33 channels of bandwidth 3KHz, bit rate 100bps, modulation BPSK/PCM) and frequencies 401.1-401.4MHz for domestic DCPs (400 channels of 750Hz spacing, bit rate 600bps, modulation QBSK); polarization: right-hand circular.
- **SEM (Space Environment Monitor)** – A space particle monitor and an x-ray monitor are mounted on FY-2 to detect the space environment in proximity of the satellite, the solar activities and relevant space phenomenon. The SEM is transmitted via telemetry to the ground system.

2.1.2 Status of spacecraft

FY-2G

Launched 2014/12/31; currently stationed at 105 °E; operational.

FY-2F

Launched 13 January 2012. Currently at 112 °E as orbital storage.

FY-2E

Launched 2009/12/23 currently active at 86.5 °E. operational.

FY-2D

Launched 2006/11/15, retired from 86.5 °E, currently at 123.5 °E, retired.

FY-2C

Launched 2004/10/09, used to be stationed at 105 °E before retirement to 123.5 °E Oct 2009, from there it was abandoned.

FY-2B

Launched 2000/06/25, used to be stationed at 105 °E. On 2001/02/28 the S-VISSR transponder failed; In June 2001 the transponder was recovered by carefully controlling the satellite temperature. EIRP (effective isotropic radiated power) was still

lower than the normal level. Temperature control was energy consuming, so during eclipse, S-VISSR had to be off. After 2003/06/08, it's only used to observe the northern hemisphere till de-missioned to 123.5 °E in Sep, 2004. On 2006/08/31, it was abandoned.

FY-2A

Launched 1997/06/10; used to be stationed at 105 °E. Intermittent operation had to be implemented due to S-band antenna failure. Moved to 86.5 °E in July 2000 and de-orbited in 2006.

2.1.3 Ground segment matters

The FY-GEO ground segment consists the Command and Data Acquisition Stations(CDAS); the Data Processing Centre (DPC), the Satellite Operation Control Centre (SOCC) ; Ranging Stations (one primary station, three secondary stations including one back-up in Melbourne, Australia). The ground segment also includes the DCPs, and HRIT/LRIT stations.

2.1.4 Data transmission

FY-2 transmits data in real time.

- **Command and Data Acquisition Station (CDAS)** Main transmission characteristics: frequency 1681.6 MHz, bandwidth 14 MHz, linear polarisation, data rate 14 Mbps.
- **S-VISSR Data Transmission**, compatible with MDUS acquisition stations, main features:
 - frequency: 1687.5 MHz; bandwidth: 2.0 MHz; polarisation: linear
 - antenna diameter ~3m, G/T~12dB/K, data rate 660kbps.
- **WEFAX** from FY-2A/B, **LRIT** (Low Rate Information Transmission) from FY-2 C/D; Main features of LRIT:
 - frequency: 1691.0 MHz; bandwidth: 260kHz; polarization: linear
 - antenna diameter ~ 1m, G/T ~ 3dB/K, data rate 150kbps.

2.1.5 Projects, services

Dual satellite scanning mode:

Operationally the FY-2 observations at 86.5 °E and 105 °E interleave so that the CDAS alternatively receives data transmission from two satellites. FY-2(105 °E) transmits at each hour time, FY-2(86.5 °E) at half hour.

2.1.6 User statistics

FY-2 satellites provide DB service (HRIT format) to users; or users can get access to FY-2 data dissemination via the CMACast system. There are 2,525 deployed CMACast receiving terminals, in which 22 overseas; and over 500 HRIT stations according to statistics of the Shinetech Company, which develops and supports Feng Yun satellite users with receiving equipment.

2.2 Status of current LEO satellite systems

The current LEO satellite system that CMA is operating is the FY-3 series satellites flying on AM and PM orbits.

Table 2 - Current Feng Yun Polar-orbiting Satellites
(as of 15 May 2016)

Orbit type (equatorial crossing times)	Satellite in orbit (+operation mode) P=Pre-operational Op=operational B=back-up L-limited availability R=R&D	Operator	Equatorial Crossing Time A=Ascend (northward) D=Descend (southward) +Altitude	Launch date	Other information
Sun-Synchronous Local "early morning" orbit (05.00-07.00) (17.00-19.00)	N/A	CMA			
Sun-Synchronous Local "morning" Orbit (07.00-12.00) (19.00-24.00)	FY-3C(Op)	CMA	10.15(D) 836 km	23 Sep 2013	AHRPT Transmission: VIRR, MWRI, IRAS,MWTS-2, MWHS-2, GNOS TOU/SBUS, SIM-2 ERM, SEM Transmission: MERSI
Sun-Synchronous Local "afternoon" Orbit (12.00-17.00) (00.00-05.00)	FY-3B(Op)	CMA	13.38 (A) 836 km	5 Nov 2010	AHRPT Transmission: VIRR, MWRI, IRAS,MWTS, MWHS, TOU/SBUS, SEM,SIM ERM MPT Transmission: MERSI

2.2.1 Mission objectives, payload/instruments

Primary objectives

The FY-3 polar-orbiting satellite series is developed for LEO service from 2008 to 2020 or beyond. Basically, the FY-3 are capable of global atmospheric sounding, IR/VIS/Microwave imaging, and ozone detection. There is plan to develop the capability of atmospheric composition measurement, or precipitation sounding with radar for future missions.

FY-3 payload/instruments

- **VIRR (Visible and Infra-Red Radiometer)**, flying on FY-3A/B/C, 10-channel VIS/IR radiometer for multi-purpose imagery, resolution 1.1 km, swath 2800 km.
- **MERSI (Medium Resolution Spectral Imager)**, flying on FY-3A/B/C, 20- channel radiometer (19 in VIS/NIR/SWIR + one TIR at 10.0-12.5 μ m) for ocean color and vegetation indexes. Resolution 250m for 4 VIS/NIR and the TIR channel, 1 km for other channels; swath 2800 km.
- **MWRI (Micro-Wave Radiation Imager)**, flying on FY-3A/B/C, 6-frequencies / 12 channels (all frequencies in double polarization) for multi-purpose MW imagery. Conical-scanning radiometer, resolution 9.5 x 15 km at 90 GHz, 30 x 50 km at 19GHz, swath 1400 km.
- **IRAS (Infra Red Atmospheric Sounder)**, flying on FY-3A/B/C, 26-channel IR radiometer (including one VIS) for temperature/humidity sounding, resolution 17 km, swathe 2250 km.
- **MWTS (Micro-Wave Temperature Sounder)**, flying on FY-3A/B, 4-channel MW radiometer for nearly-all-weather temperature sounding, 54 GHz band, resolution 70 km, cross-track scanning, swath 2200 km.
- **MWTS-2 (Micro-Wave Temperature Sounder)**, flying on FY-3C/D/E, 13-channel MW radiometer for nearly-all-weather temperature sounding, 54 GHz band, resolution 70 km, cross-track scanning, swath 2200 km.
- **MWHS (Micro-Wave Humidity Sounder)**, flying on FY-A/B, 4 frequency / 5 channel (one frequency in double polarization) MW radiometer for nearly-all-weather humidity sounding. 183GHz band, resolution 15 km, cross-track scanning, swath 2700 km.
- **MWHS-2 (Micro-Wave Humidity Sounder)**, flying on FY-C/D/E/F, 15 channel MW radiometer for nearly-all-weather humidity sounding. 183GHz band, resolution 15 km, cross-track scanning, swath 2700 km.
- **TOU/SBUS (Total Ozone Unit and Solar Backscatter Ultraviolet Sounder)**, flying on FY-3A/B, a suite of two UV spectro-radiometers, one (TOU) with 6 channels in the 308-360 nm range, resolution 50 km, swath 3000 km, for total ozone; the other one (SBUS) with 12 channels in the range 252-340 nm, resolution 200 km, nadir viewing, for ozone profile.
- **SEM (Space Environment Monitor)**, flying on FY-3A/B/C/D/E, for in situ observation of charged particles in proximity of satellite.
- **ERM (Earth Radiation Measurement)**, flying on FY-3A/B, 2 broad-band channel radiometer for earth reflected solar flux and earth emitted thermal flux over total (0.2-50 μ m) and short (0.2-4.3 μ m) waveband; resolution 28km, cross-track scanning with 2 degree NFOV, swath 2300 km, nadir viewing with 120 degree WFOV.

- **SIM (Solar Irradiance Monitor)**, flying on FY-3A/B, 3-channel radiometer over 0.2-50 μ m waveband for the total incident solar flux; viewing the Sun near the north pole area.
- **GNOS (GNSS Occultation Sounder)**, flying on FY-3C/D/E/F; receives signal from GPS or China BeiDou satellites; observing over 1000 occultation events per day.

2.2.2 Status of spacecraft

FY-3C

Launched 2013/Sep/23, operational.

FY-3B

Launched 2010/Nov/5. It's the same model as FY-3A, the design life-time is 3 years, 3 axis stabilized, sun-synchronous, taking the afternoon orbit. FY-2B carries similar instruments on FY-3A.

FY-3A

Launched on 2008/May/27, designed life-time 3 years, 3-axis stabilized, sun-synchronous, taking morning orbit. Service ends 5 Jan 2015.

FY-1D

Launched on 15 May 2002 with identical mission objective as the FY-1C; the last satellite of FY-1 program. FY-1D had been working 9 years till 6 May 2011 when power supply was becoming too weak to maintain the attitude stable. In Sept. 2011 FY-1D was de-missioned.

FY-1C

Launched 10 May 1999. Some improvement seen from its predecessors. The size of solar panel was enlarged, the VIRR has ten channels. The attitude stability is much improved. It had been operating for nearly 5 years. Data acquisition and archive for FY-1C at NSMC ceased 6 April 2001 for good due to obvious degradation of measurements. The satellite was de-missioned afterwards.

FY-1B

Launched on 2 September 1990. It's a copy of FY-1A. A series tests was performed on the spacecraft and to demonstrate the ground system. The satellite is de-missioned in August 1991 due to attitude control failure.

FY-1A

Launched on 7 September 1988. As the first meteorological satellite ever made by China, it was used to test and demonstrate the system. The VIRR instrument had five channels (0.58-0.68 μ m, 0.725-1.1 μ m, 0.48-0.53 μ m, 0.53-0.58 μ m, 10.5-12.5 μ m). Satellite failure was announced not long after launch when the satellite attitude control became impossible.

2.2.3 Ground segment matters

CMA operates four ground stations to receive the FY polar orbiting satellite data. The ground stations are located in Beijing, Guangzhou, Urumuqi, and Jiamusi. The

received data are relayed to the Data Processing Center(DPC) through optical fiber link. The data is processed into various products and to be disseminated or archived.

NSMC uses 2 antennas at the North Pole Satellite Station of Esrange Space Center, Kiruna, Sweden to receive FY-3 satellites under contract between CMA and SSC(Sweden Space Company) of long term on-orbit services for FY-3 and other polar satellite to be operated by NSMC. SSC receives downlinks of FY-3 at the Esrange Ground Station and transfers the data to the Beijing DPC.

2.2.4 Data transmission

FY-3s provide X-band (MPT) and L-band (AHRPT) direct broadcast services.

• **MPT (Medium-resolution Picture Transmission)**, for full information transmission of MERSI measurement on FY-A/B/C. Main features:

- frequency: 7775MHz; bandwidth: 45 MHz; polarization: right hand circular;
- antenna diameter ~ 3 m, G/T ~ 21.48 dB/K, data rate 18.7 Mbps.

• **AHRPT (Advanced High Resolution Picture Transmission)** for full information transmission of the instruments exclusive of the MERSI on FY-3A/B/C. Main features:

- Frequency: in the range 1704.5MHz; bandwidth: 6.8MHz; polarization: right hand circular.
- Antenna diameter ~ 3 m, G/T ~ 6.8 dB/K, data rate: 4.2 Mbps.

• **DPT (Delayed Picture Transmission)** for dump data transmission. .

- Frequency: 8146 MHz; bandwidth 149 MHz, data rate: 9.3 Mbps.

2.2.5 Projects, services

Pre-processing software package for FY-3 satellites

NSMC/CMA releases two software packages FY3L0pp and FY3L1pp to help FY-3's DB users processing the X-band and L-band data both in CCSDS format. The two software packages are capable of processing raw data of 4 instruments (namely MERSI, VIRR, MWTS, and MWHS) on FY-3A/B, and 5 instruments (the above-mentioned 4 instruments plus MWRI) on FY-C. The package and ancillary data are made available at following page on NSMC website.

<http://www.nsmc.cma.gov.cn/en/NSMC/Channels/Tools.html>

For more information about the package please refer to CMA working paper CGMS-39 (CGMS39-CMA-WP-16).

2.2.6 User statistics

According to information from the Shinetech Company, which develops and installs the HRPT user stations, over a hundred HRPT terminals were deployed across China based on statistics in 2012.

3 FUTURE SATELLITE SYSTEMS

3.1 Status of future GEO satellite systems

According to FENG YUN program, the Feng Yun 4(FY-4) – CMA new generation geostationary meteorological satellite, a three-axis stabilized platform, is being developed. Launch of the first flight model (FY-4A) is scheduled for 2016, for the system test and demonstration.

In the meantime, FY-2 series is looking forward to the arrival of FY-2H in 2017 for smooth transition into the FY-4 time.

Table 3 - Future Feng Yun Geostationary Satellites
(as of May 15, 2016)

Sector	Future additional satellites	operator	Planned launch	(planned location) Other remarks
Indian Ocean (36°E-108°E)	FY-4A	CMA	2016	(TBD) AGRI, GIIRS, LMI, SEM,DCS
West-Pacific (108°E-180°E)	FY-2H	CMA	2017	(TBD) 5 channel VISSR, SEM, DCS

3.1.1 Mission objectives, spacecraft, payload/instruments, products

The main mission objectives of FY-4A

- To take multiple spectral imagery of the earth with high temporal resolution;
- To measure the vertical profile of temperature and humidity of the atmosphere with improved vertical resolution and detection accuracy.
 - To detect and map positions of lightning occurrences.
 - To monitor solar activities and space environments for space weather research and service.
 - To collect data from data platforms and transmit users.
 - To broadcast observational images, data and derived products with onboard transmitter.

The FY-4 payloads / instruments

- **AGRI (Advanced Geo. Radiation Imager):** multi-spectral imager with two independent mirrors scanning north-south and east-west directions respectively; 216 sensors in 14 bands from visible to long-wave infrared (0.55~13.8 μ m); on-board calibration for all bands, full optic length of radiation considered in calibration; resolutions : 500m x1(ch), 1km x 2(ch), 2 km x 4(ch), 4km x 7(ch); S/N: 90~200. NE Δ T: 0.2~0.7K; full disk time<15min.

- **GIIRS (Geo. Interferometric Infrared Sounder):** two independent mirrors scanning north-south and east-west directions respectively; 32 x 4 plane arrays for mid-wave (375 S/MIR channels) and long-wave infrared bands (538 LWIR channels); resolution: 16km; active and radiate coolers; radiometric calibration accuracy: 1K; spectral calibration accuracy: 10ppm; Mesoscale: 35 min (1000x1000km), China area: 67 min (5000x5000km).
- **LMI (Lightning Mapping Imager):** two tubes for observation to achieve more spatial coverage; central frequency: 777.4nm; S/N ≥ 6; spatial resolution: 7.8km; temporal resolution: 2ms.
- **SEM(Space Environment Monitoring):** including a Magnetometer for 3-D magnetic field intensity; an Energetic Particle Detector for monitoring high-energy electron storms and proton events; and Space Weather Effect Detectors for the impact of space weathers on satellite.

3.1.2 Data transmission

FY-4 provides 1675 -1687 MHz **HRIT** (High Rate Image Transmission), 1696-1698 MHz **LRIT** (Low Rate Image Transmission) and **WAIB** (Weather Alarm Information Broadcast) services.

- **Raw data transmission** (downlink): to CDAS with X –band 7450-7550 MHz (CR and CL);
 - **HRIT:** data uplink: 8175-8215 MHz; data downlink: 1675-1687 MHz
 - **LRIT and WAIB:** data uplink: 2056–2060 MHz; data downlink: 1696-1698 MHz
 - **DCS:** domestic channels: 401.1-401.4 MHz (data uplink)
International channels: 402.0-402.1 MHz (data uplink)
Data downlink: 1686-1692 MHz
 - **TARS:** 2042-2052 MHz (uplink: frequency extent)
1689-1697 MHz (downlink-1), 2222-2232 MHz(downlink-2)
 - **Telemetry and command:** 2025-2110MHz (uplink)
2200-2290 MHz (downlink)

3.2 Status of future LEO satellite systems

Program planning enables FY-3 service into 2020s, to be covered by FY-3D/E/F/G, taking both morning (AM) and afternoon (PM) orbits. A model is being developed for early morning orbit.

Table 4 – Future Polar-Orbiting Satellite Coordinated within CGMS
(as of 15 May 2016)

Orbit type	Satellite in orbit	Operator	Equatorial Crossing Time	Launch date	Other information
(equatorial crossing)			A=Ascend		

times)			(northward) D=Descend (southward) +Altitude		
Sun- synchronous Local "early morning" orbit (05.00-07.00) (17.00-19.00)	FY-3E	CMA	Early morning	2018	AHRPT X-band Transmission: FMERSI, MWTS-2, MWHS-2, WindRAD, HIRAS, GNOS, SWS
Sun- Synchronous Local "morning" Orbit (07.00-12.00) (19.00-24.00)	FY-3F	CMA	10.00(D) 836 km	2019	AHRPT X-band Transmission: MERSI-2, HIRAS, MWRI, MWTS-2, MWHS-2, GAS, GNOS
Sun- Synchronous Local "afternoon" Orbit (12.00-17.00) (00.00-05.00)	FY-3D	CMA	14.00 (A) 836 km	2016	AHRPT X-band Transmission: MERSI-2, HIRAS, MWRI, MWTS-2, MWHS-2, GAS, GNOS, SWS
Sun- Synchronous Local "afternoon" Orbit (12.00-17.00) (00.00-05.00)	FY-3G	CMA	14:00 (A) 836 km	2021	AHRPT X-band Transmission: MERSI-2, MWTS-3, MWHS-2, MWRI, GAS, HIRAS, GNOS, SWS

3.2.1 Mission objectives, spacecraft, payloads / instruments

Similar to FY-3A/B/C, which have already been launched, future FY-3 models are able of the earth measurements, real-time transmission for the operational use of IR/MW atmospheric sounding data, and VIS/IR/MW imaging data. CMA plans to develop atmospheric composition measurements, rainfall measurement for future FY-3s.

Table 5 - Instruments & Deployment schedule for FY-3D/E/F/G/RM

Suites	Satellite & Deployment	3D(pm) 2016	3E(early am) 2018	3F(am) 2019	3G(pm) 2021	3RM 2020
	Instruments					
Optical imager	MERSI-2	●	FMERSI	●	●	●
	MWTS-2	●	●	MWTS-3	MWTS-3	MWTS-3
MV Passive	MWHS-2	●	●	●	●	●
	MWRI	●		●	●	●
Occultation	GNOS	●	●	●	●	●

MV Active	WindRAD		•			
	Rainradar					•
Hyper-spectral detector	HIRAS	•	•	•	•	
	GAS	•			•	
	OMS			•		
Radiation measurement	ERM			•		
	Solar Radiation Monitor		•	•		
	Solar Irradiance spectrometer		Two in one			
Space weather suite (SWS)	SEM	•	•			
	WAI	•			•	
	IPM	•	•	•	•	
	XEUVI		•			

Payloads / instruments

- **MERSI-2 (Medium Resolution Spectral Imager-2)**, to fly on FY-3D/F/G, it's the advanced model of medium resolution spectral imager, with 25 channels (the old model has 20 channels). The VIRR channels are merged.
- **FMERSI (Faint-light Medium Resolution Spectral Imager)**, to fly on the early-morning satellite observing faint objects.
- **MWTS-2 (Micro-Wave Temperature Sounder-2)**, flying on FY-3C/D/E, 13-channel MW radiometer for nearly-all-weather temperature sounding, 54 GHz band, resolution 70 km, cross-track scanning, swath 2200 km.
- G
- **MWTS-3 (Micro-Wave Temperature Sounder-3)**, flying on FY-3F/G, improved model of microwave temperature sounder, with 23.8GHz and 31.4 GHz included.
- **MWHS-2 (Micro-Wave Humidity Sounder-2)**, flying on FY-C/D/E/F/G, 15 channel MW radiometer for nearly-all-weather humidity sounding. 183GHz band, resolution 15 km, cross-track scanning, swath 2700 km.
- **WindRAD (Wind Radar)**, to fly on FY-3E for global ocean surface wind field (OSWF); measure the radar backscattering of sea surface from different azimuth and then retrieve wind vector with the geophysical model function (GMF). Two bands: C-band (5.3GHz, polarization: HH, VV, resolution: 25 km (azimuth direction) and ≤10 km (range direction)); and Ku-band (13.256GHz; polarization: HH, VV; resolution: ~ 10 km (azimuth direction) and ≤5 km (range direction)); swath: > 1200 km; rotation rate: 0.4207 rad/s.
- **HIRAS (Hyperspectral Infrared Atmospheric Sounder)**, to fly on FY-3D/E/F/G, similar to IASI flying on Metop satellite for improved measurement of temperature and humidity. Spectral range: 650-1138cm⁻¹, (LWIR, spectral resolution: 0.625cm⁻¹), 1210-1750cm⁻¹(MWIR, spectral resolution: 1.25cm⁻¹), 2155-2500cm⁻¹(SWIR, spectral resolution: 2.5cm⁻¹); spatial resolution: 16 km at arranged in 2x2 array. Scan angle: ± 50.4° around nadir.

- **GAS (Greenhouse Gases Absorption Spectrometer)**, to fly on FY-3D/G for global measurement of CO₂ and CH₄.
- **OMS (Ozone Mapping Spectrometer)**, to fly on FY-3F; an Envisat /SCIAMACHY-like instrument for the detection of ozone and other atmospheric chemicals. It replaces the suite of TOU and SBUS on early FY-3s. The total column content and the profile of trace gases can be retrieved from the nadir view and limb view separately. Nadir direction - spectral range 300~500nm: for O₃ and trace gases total column, spatial resolution 15x25 km; spectral range: 250~310nm: for O₃ profile, spectral resolution 34x60 km; Limb direction – spectral range: 290~500nm for O₃ and trace gases, resolution 3 km.
- **GNOS (GNSS Occultation Sounder)**, to fly on FY-3C/D/E/F/G; receiving signal from GPS and China BeiDou; observing over 1000 occultation events per day with GPS and BeiDou satellites.
- **WAI (Wide-angle Aurora Imager)**, flying on FY-3D/G, imaging the ionospheric phenomenon of aurora in solar wind.
- **IPM (Ionospheric PhotoMeter)**, flying on FY-3D/G, for measurement of the illuminous intensity at the ionosphere.
- **MAIPM (Multi-angle Ionospheric PhotoMeter)**, flying on FY-3E, for OI136.5nm and N₂LHB band airglow intensities near the solar terminator line.
- **XEUVI (Solar X-EUV Imager)**, to fly on FY-3E, imaging the phenomenon of solar activities at x-ray and extreme ultraviolet.

4 CONCLUSION

Tremendous efforts have been made for the establishment and improvement of FENG YUN GEO and LEO systems. The Feng Yun Program is long term, application-oriented, and the user community will get benefit from its continuous development pursuing quality Earth Observation data and products for weather, climate, and environment services.