Recent Progress of Fengyun Meteorology Satellites

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Abstract

After nearly 50 years of development, Fengyun Satellite ushered in its best moment. China has become one of the three countries or units in the world (China, USA, and EU) that have both polar and geostationary meteorological satellites. Merely in the past two years, three meteorological satellites have been launched, which were FY4A launched on Dec. 11, 2016, FY3D launched on Nov. 15, 2017 and FY2H launched on June. 5, 2018. This report mainly describes the main features of the three satellites and their payloads on-board them. Nowadays, the Fengyun satellite data service has been applied to all fields, not only in the meteorological but also in agriculture, hydraulic engineering, environmental, education, scientific research and other industries.

Key words

Fengyun meteorology Satellites, Fengyun-3 polar-orbit satellite, Fengyun-4 geostationary satellite, Fengyun-2 geostationary satellite

1. Background Introduction of Fengyun Meteorology Satellites

Since the first meteorological satellite, Television, and Infrared Observational Satellite (TIROS 1), was launched on 1 April 1960, meteorological satellites have become indispensable for studying the Earth's atmosphere. Together with their land-and ocean-sensing cousins, meteorological satellites view the Earth from a global perspective that is unmatched by any other observing system (Kidder and Vonder Haar 1995).

Chinese satellite meteorology started in 1970 with the formation of the National Satellite Meteorological Center (NSMC) (Fang *et al*. 2004; Yang *et al*., 2008; Zhang *et al*., 2009). The first sun-synchronous orbital meteorological satellite, FY-1A, was launched in 1988 and the first geostationary orbital meteorological satellite, FY-2A, was launched in 1997. Since FY-1C in 1999 and FY-2C in 2004, China completed the transition from research and development satellite to the operational satellite on a sun-synchronous orbit and geostationary orbit successively (Li 2001, Meng 2004). Since FY-3A in 2008, China completed the transition from the first generation to second generation on a sun- synchronous orbit (Dong *et al*, 2009; Yang *et al*., 2011, 2012; Zhang *et al*., 2015). Currently, China has become one of the few countries who operationally maintain sun-synchronous and geostationary meteorological satellites. Chinese meteorological satellites are becoming an important component of the space-based global observing system organized by the World Meteorological Organization (WMO).

Chinese meteorological satellites fall into two categories (Li, 2001; Zhang, 2001; Meng, 2004): the polar orbit series and the geostationary orbit series. Each satellite is named with an Arabic numeral and a letter. The Arabic numerals represent the satellite series, odd numbers being the polar orbit satellites and even the geostationary satellites. The letter represents the sequence number within the series. So far, eight polar orbit satellites and nine geostationary satellites have been launched successfully (Table 1). Among them, 9 satellites have

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been retired and 8 satellites are currently operating in orbit, which provides a large number of global and regional Earth observations for application in the fields of meteorology, oceanography, forestry, agriculture, civil aviation, and military.

Since 2016, three Fengyun series satellites have been launched, which are FY4A launched on Dec. 11, 2016, FY3D launched on Nov. 15, 2017 and FY2H launched on June 5, 2018. In this report, a brief introduction will be given to these recent launched Fengyun Satellites, including the sensors on a satellite, the features of the satellites and the applications.

Table 1 Chinese meteorological satellites

Satellite name	Type	Launch date	Function
FY-1A	polar	Sept. 7, 1988	Experimental (Retired)
FY-1B	polar	Setp. 3, 1990	Experimental (Retired)
FY-1C	polar	May 10, 1999	Operational(Retired)
FY-1D	polar	May 15, 2002	Operational(Retired)
FY-3A	polar	May 27, 2008	Experimental(Retired)
FY-3B	polar	Nov 5, 2010	Experimental(On-orbit)
FY-3C	polar	Sept. 23, 2013	Operational(On-orbit)
FY-3D	polar	Nov 15, 2017	Operational(On-orbit test)
FY-2A	geostationary	June 10, 1997	Experimental(Retired)
FY-2B	geostationary	June 25, 2000	Experimental(Retired)
FY-2C	geostationary	Oct. 18, 2004	Operational(Retired)
FY-2D	geostationary	Dec. 8, 2006	Operational(Retired)
FY-2E	geostationary	Dec. 23, 2008	Operational(On-orbit)
FY-2F	geostationary	Jan. 13, 2012	Operational(On-orbit)
FY-2G	geostationary	Dec. 31, 2014	Operational(On-orbit)
FY-2H	geostationary	June. 5, 2018	Operational(On-orbit test)
FY-4A	geostationary	Dec. 11, 2016	Experimental(On-orbit)

2. Fengyun Satellite Data Resources and Service

2.1 Data Resources

NSMC (National Satellite Meteorology Centre) preserves data from Chinese and foreign satellites since 1983. By the end of 2017, NSMC has stored data volume up to 10PB from 25 spacecraft, 122 product catalogs. FENGYUN series satellite data and product are the absolute majority of the total archive. The daily archive data volume is increasing rapidly to 8500GB/day in 2017 (see Figure 1).

2.2 Data Service

Fengyun satellites data center has an open data policy (Qian J M *et al*., 2012). Users can access Fengyun satellites data by three main ways. (1) For those who want to use real-time data, users could build a set of the direct receiving system by themselves. This is the fastest way to get Fengyun satellite data. (2) Near real time data users in Asia-Oceanic area could establish a CMACast receiving system. (3) from 2005, NSMC has built a Fengyun satellite data service based on the internet (http://data.nsmc.org.cn). Fengyun satellites data center provide 25 satellites, including FY-1, FY-2, FY-3, FY-4 and other satellite data receiving or collecting by NSMC, and 122 catalog datasets in L1 and higher level products, such as atmosphere, land surface, ocean surface, space weather and radiation data products.

Over the past 10 years, more than 60 thousand users registered on the Fengyun satellite data service website by the end of 2017. More than 3.1PB satellites' data has been delivered to domestic and international users in 2017. Fengyun satellite data service website has become the most important way by which users can get Fengyun satellites data. More than 70% in total data services' volume is contributed by the internet downloading. Everyone can become a registered user and download data freely. Most of the users came from China and about 5% foreign users coming from more than 86 countries and regions. Figure 2 shows user map

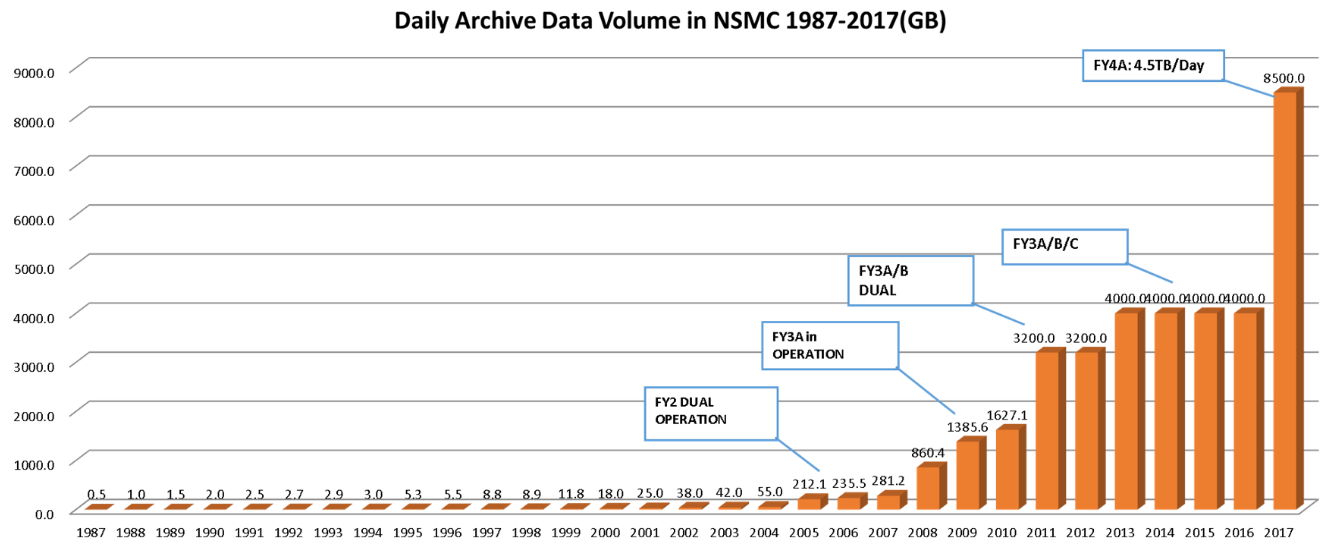

Fig. 1 Statistics of daily archived data volume

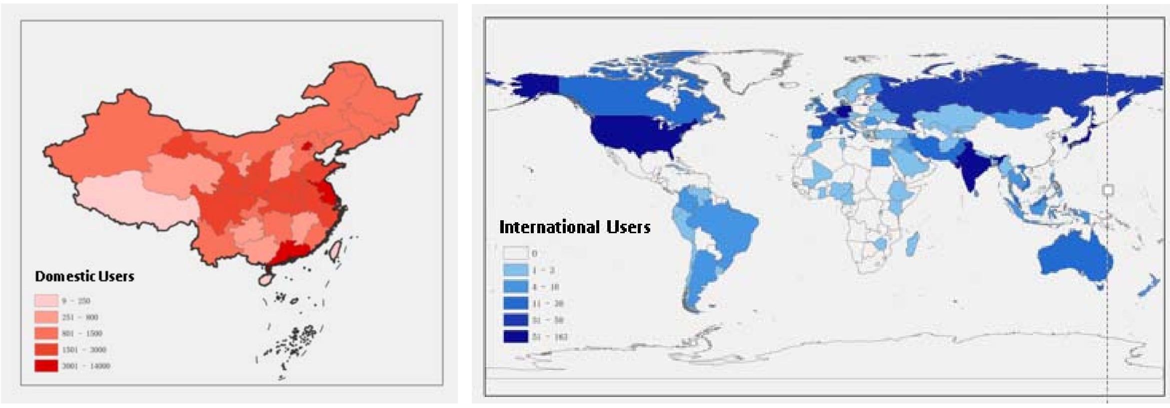

Fig. 2 Fengyun satellite data user distribution map around in China (left) and the world (right)

in China and world. The total user number in each province is correlated with the number of universities, population, and the development of region remote sensing applications.

Among the participating users, scientists are 39.5%, students are 25%, operation staffs are 23.3%, teachers are 7% and management are 4%. Regarding the users' field, most of them come from meteorological systems(63%), 8% users come from academics, 5% users come from agriculture departments, other users work with environmental detection(5%), ocean remote sensing(4%) and so on. Fengyun satellite data are mostly used in meteorological science, and data can also be used in many other scientific fields.

2.3 Introduction to the Web Service of FY Satellite Data

The Fengyun satellite data center was built on the enormous data archive and service system of Fengyun Ground Application System. With over 10 petabytes data retrieved from more than 30 meteorological satellites and environmental satellites, the website of Fengyun satellite data center (http://data.nsmc.org.cn) is one of the main ways to access Fengyun satellite data, especially for those who want the long-term earth observation data. FY-1 and FY-3 data which covers the whole earth, FY-2, and FY-4 data which covers from east European and Africa to the edge of east Pacifica, Transat data, which is the first carbon dioxide monitoring satellite of China, and satellite data from U.S.A., European, and Japan can also be found on this website. Users can search, select, customize, order and download data and products with a simple registration. The documentation and applications which can help user using Fengyun satellite data also can be found on the website. For agencies and websites who want to access Fengyun satellite data, the API interfaces are also provided.

Fengyun satellite data center website (see Figure 3) is

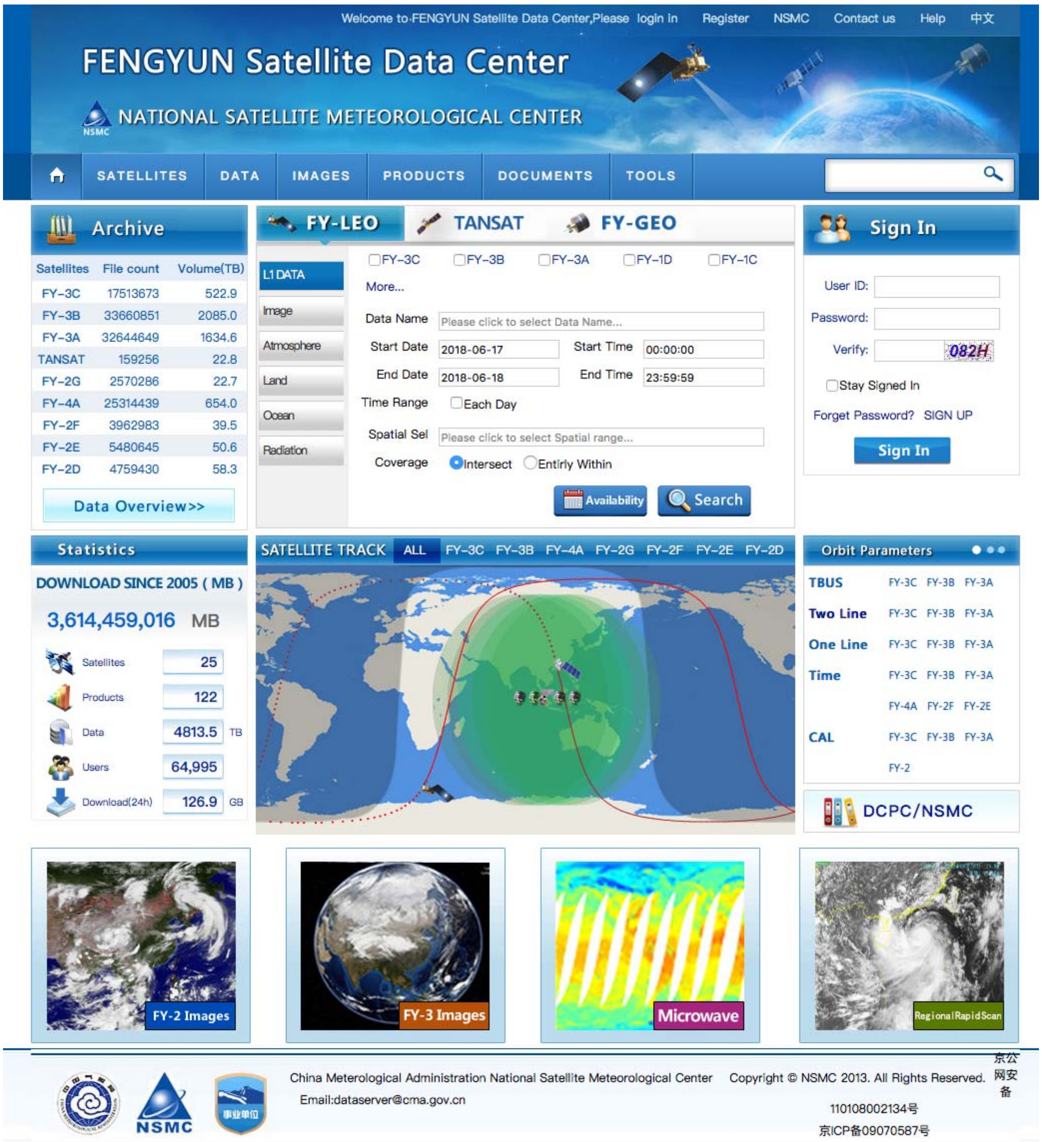

Fig. 3 Web interface of Fengyun satellite data center

running by the National Satellite Meteorological Center of CMA, which has made a great contribution to meteorological and climate researches, environment detection, and other fields including about 100 industries. With the gradual expansion of social and international influence, the website has served over 60 thousand users from about 83 countries, including 37 "Belt and Road" countries since 2005.

3. Updated Progress of FY Satellites

3.1 FY3D-the Fourth Satellite of China's Second Generation Polar-orbiting Meteorological Satellite

FY-3D, which is the fourth satellite in China's second generation polar-orbiting meteorological satellite family, is designed to run for five years. It is equipped with 10 advanced remote sensing instruments. In addition to five inherited instruments such as microwave thermometer, microwave hygrometer, microwave imager, space environment monitoring toolkit and global navigation satellite occultation detector, the infrared hyperspectral atmospheric sounder, near-infrared hyperspectral GHG monitor, wide-angle aurora imager and ionospheric photometer are newly developed and installed onboard for the first time. Among the core instruments, the resolution of spectral imager has been significantly upgraded and improved. Figure 4 and Figure 5 give some information about the FY3D satellite platform and the instruments on it.

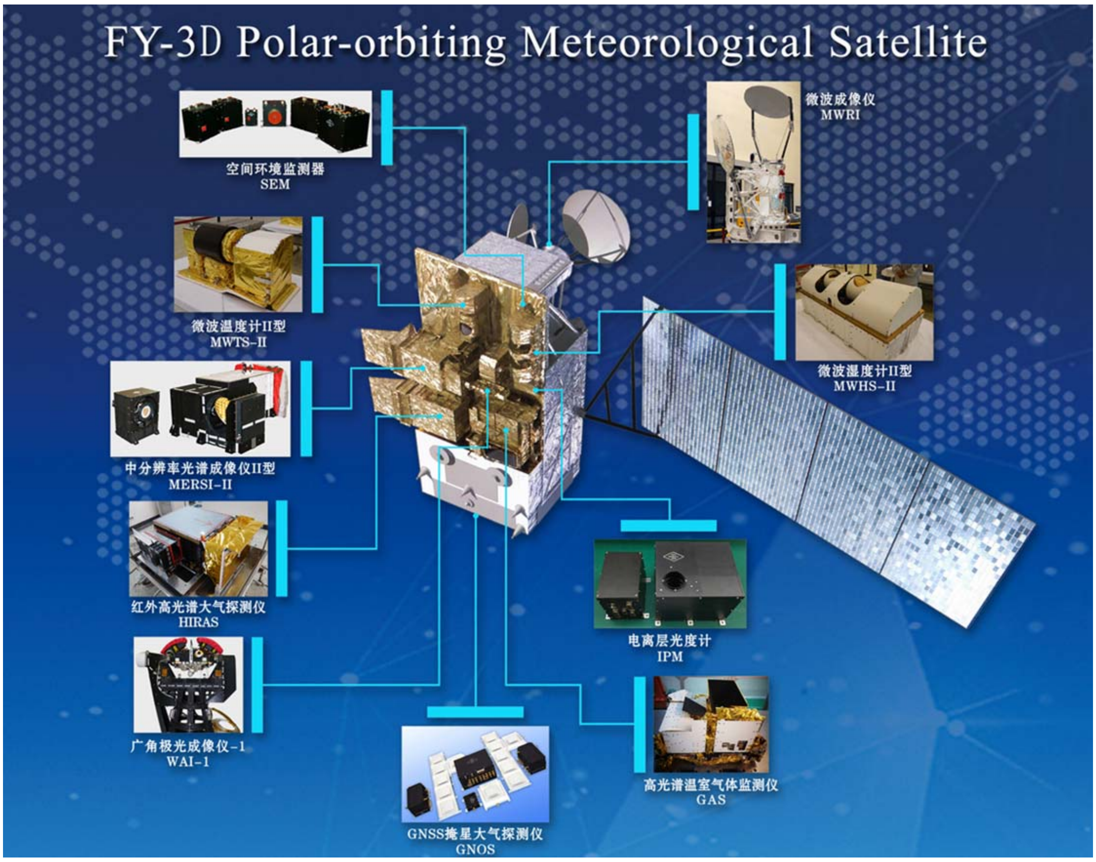

Fig. 4 Instruments onboard FY3D

Payload	Number of channels (start-stop wavelength)
the Medium Resolution Spectral Imager – Model II (MERSI-II)	25（0.413-12μm）
the Hyperspectral Infrared Atmospheric Sounder (HIRAS)	1370（3.92 -15.38μm）
the Micro-Wave Radiation Imager (MWRI)	10（10.65-89 GHz）
the Micro-Wave Temperature Sounder – Model II (MWTS-II)	13（50.3-57.29GHz）
the Micro-Wave Humidity Sounder– Model II (MWHS-II)	15（89.0-183.31 GHz）
the GNSS Radio Occultation Sounder (GNOS)	29 (none)
the Greenhouse Gases Absorption Spectrometer (GAS)	5540（0.75-2.38μm）
the Wide-angle Aurora Imager (WAI)	1（140nm-180nm）
the Ionospheric PhotoMeter (IPM)	3（130-180 nm）
the space environment monitor (SEM)	25 (none)

Parameter	Indicator
Orbital type	Near polar sun synchronous orbit
Orbital height	836 km
Orbital inclination	98.75°
Injection accuracy	Deviation of semi-major axis: $\lvert\Delta a\rvert \le 5$ km
	Deviation of orbital inclination: $\lvert\Delta i\rvert \le 0.1°$
	Orbital eccentricity: ≤0.003
Return cycle	5.5 days (a designed period of 4 to 10 days)
Eccentricity	≤0.0025
Excursion of nodical local time	Less than 15 min in 4 years
Launch window	Ascending nodical local time 13:40-14:00
Satellite life	Designed to be 5 years long, assessed at year 4

Fig. 5 Parameters of satellites FY3D and the main payloads

FY-3D is a satellite with the largest number of spectral measurement channels (over 7000) in China, which will greatly enhance the capacity to detect the low-altitude atmospheric dynamic parameters, thermal parameters, GHGs and high-altitude atmospheric electricfields, magnetic fields and energetic particles of the earth, hence the capabilities and skills in such aspects as global NWP, global climate change response, ecological environment monitoring and space weather forecasting in China.

After being launched and going through the in-orbit testing, FY-3D will be put into operation as a principal satellite for low-orbit afternoon observation in China. It will be networked together with FY-3C, which was launched in September 2013, as part of a constellation of morning and afternoon observation by China's polar-orbiting meteorological satellites of a new generation. By then, China will be the No.1 operator of in-orbit meteorological satellites by number and by variety in the world. According to incomplete statistics, at present, as many as 77 countries and regions receive and apply FY meteorological satellite data, 37 of which are situated along or around the Belt and Road. This satellite family, which represents China's strength and reputation globally and internationally, contributes to the earth observation. Its incorporation in the Global Earth Observation Satellite Program by the World Meteorological Organization (WMO), a UN specialized agency, will lead to an improved duration and accuracy in forecasting by the state-of-the-art national and international mid-and long-term NWP models. This family, which is also tasked with the Chinese on-duty mission under the International Charter on Space and Major Disasters, plays an increasingly important role in the international effort in meteorological disaster management. Table 2 shows the main instruments on-board FY3D and their parameters.

3.1.1 New Instruments On-board FY-3D

The Infrared Hyperspectral Atmospheric Vertical Sounder (HIRAS), which uses the most advanced Fourier interference detection technology in the world, observes the systems of land and air in a hyperspectral resolution and in an infrared fashion, with the spectrum covering 1370 channels. Compared with the existing FY-3 IR spectrometer, the number of spectral channels is increased by 70 times, with the spectral resolution being up to a wave number of 0.625 cm, which improves the accuracy of atmospheric temperature and humidity in profile inversion by more than one time as a much stronger support to China's long-term NWP by extending the lead time of weather forecasting by 2-3 days.

The Hyperspectral Greenhouse Gas Monitor (GAS) is the first remote sensing instrument carried onboard a FY satellite to watch global GHG concentrations. It captures the information on concentrations of major GHGs (carbon dioxide, methane and monoxide) in their global distribution over time to improve the quantitative estimation of surface GHG fluxes at regional scale, and the analysis and monitoring of global carbon sources and sinks as a robust body of data in support of GHG reduction set forth at the Paris Climate Conference.

The Wide Angle Aurora Imager (WAI) is the first remote sensing instrument in the world to acquire aurora images from a wide spatial range of fields. At high magnetic latitudes, it takes an aurora image of the extreme ultraviolet band and of about 130°×130° every two minutes at a spatial resolution of 10 km. It monitors the location of the Aurora border, the ionospheric global image and the distribution of precipitating electrons to report the auroral intensity and range and the polar precipitating particles before forecasting a potential magnetic storm, a potential magnetospheric substorm or

Table 2 Payloads for FY-3D

No	Name	Number of channels (start-stop wavelength)	Channel description
1	Medium Resolution Spectral Imager (MERSI-II)	25 (0.413-12 μm)	
2	Infrared Hyperspectral Atmospheric Sounder (HIRAS)	1370 (3.92-15.38 μm)	
3	Microwave Imager (MWRI)	10 (10.65-89 GHz)	
4	Microwave Thermometer (MWTS-II)	13 (50.3-57.29GHz)	
5	Microwave Hygrometer (MWHS-II)	15 (89.0-183.31 GHz)	
6	Global Navigation Satellite Occultation Detector (GNOS)	29 (none)	GNOS: 9 positioning, 8 occultation; Beidou: 6 positioning, 6 occultation
7	Hyperspectral GHG Monitor (GAS)	5540 (0.75-2.38μm)	
8	Wide Angle Aurora Imager (WAI)	1 (140nm-180nm)	
9	Ionospheric Photometer (IPM)	3 (130-180 nm)	135.6 nm (day mode) N2LBH band (day mode) 135.6 nm (night mode)
10	Space Environment Detector (SEM)	25 (none)	High Energy Ion Detector 6+6, High Energy Electron Detector 5, Surface Potential Detector 2, Radiation Dosimeter 6

the polar ionospheric weather pattern.

The Ionospheric PhotoMeter (IPM) retrieves night-time electron concentrations and daytime oxygen-to-nitrogen ratio parameters by measuring the EUV band airglow radiation intensity of oxygen atoms and nitrogen molecules in order to monitor the changing ionospheric-state. WAI and IPM contribute to the safety of China's space infrastructure that underpins the national strategy of being a power in aerospace.

3.1.2 Upgraded Instruments On-board FY-3D

The MEdium Resolution Spectral Imager–Model II (MERSI-II) is one of the core instruments in the FY-3 family. When upgraded, it is comparable to the imager onboard the latest US co-polar-orbing meteorological satellite as one of the most advanced wide-image remote sensing instruments in the world. MERSI, which integrates the functions of two existing imaging instruments for FY-3, is the first imager in the world that obtains global infrared split-window data of a resolution of 250 m. It acquires global true color images of a 250 m resolution seamlessly every day to accurately and quantitatively retrieve such atmospheric, terrestrial and oceanic parameters as clouds, aerosols, water vapor, land surface features and ocean color as a scientific support to the ecological management and restoration, environmental monitoring and protection in China and as a Chinese program in observation proposed for the global ecological well-being, disaster monitoring and climate assessment.

3.1.3 Inherited Instruments On-board FY-3D

Building on the predecessor of FY-3C, the GNSS Occultation Atmospheric Sounder (GNOS) features a bigger number of positioning and occultation channels for China's Beidou navigation satellites. It is the first detector in the world that receives signals from the two navigation satellite systems of GPS and Beidou at the same time with a total of 29 receiving channels. It provides global atmospheric refractive indexes and atmospheric temperature, humidity and pressure profiles of high precision and high vertical resolution for NWP and climate monitoring in China as well as information on ionospheric electron density for space weather monitoring.

Building on its predecessor, the Microwave Hygrometer-Model II (MWHS-II) features an improvement in the accuracy in instrument radiation calibration, the sensitivity in detection and the lifetime for service. Using the five atmospheric humidity detection channels near the water vapor absorption line of 183.31 GHz and the eight atmospheric temperature detection channels near the oxygen absorption line of 118.75GHz in combination with the detection results from the two window channels of 89GHz and 166GHz, MWHS-II acquires global profiles of vertical distribution of atmospheric humidity and temperature and products like rainfall verification, path ice water thickness and precipitation intensity as the information on the initial atmospheric humidity field for NWP.

Building on its predecessor (MWTS-I), the Microwave Thermometer-Model II (MWTS-II) features an increase in the number of channels near the oxygen absorption band of 50—60 GHz from 4 to 15 by subdivision to improve the capability and performance of the microwave thermometer. It observes the atmospheric vertical temperature distribution around the clock and in all weather conditions to produce a better initial field for NWP models and a higher accuracy in weather forecasting.

The MicroWave Imager (MWRI) is one of the important imaging instruments for FY-3. The observation of the Earth's surface 10.65—89 GHz dual-polarized passive microwave radiation energy derives the information on wind field, land surface and sea surface precipitation, precipitable water, cloud water, thickness of liquid on the atmospheric path, thickness of ice water on the path, height and thickness of the melting layer, soil moisture, sea ice, sea surface temperature and snow cover. It maintains the features designed for the first three satellites as well as a stable continuous observation, hence is well placed for climate observation and research.

The Space Environment Monitor (SEM) mainly detects the particle radiation on the orbit of a satellite, the in-situ changing magnetic field vector, the accumulated instrument radiation and the changing satellite surface potential, the data from which are used to support space activities, satellite design, space research, and space weather warning and forecasting.

3.2 FY4A-the First Satellite in China's Second Generation Geostationary Meteorological Satellite

The FY-4 introduces a new generation of Chinese geostationary meteorological satellites, with the first FY-4A launched on 11 December 2016. The remaining satellites of this series are planned to be launched from 2018 to 2025 and beyond. FY-4 has improved capabilities for weather and environmental monitoring, including a new capability for vertical temperature and moisture sounding of the atmosphere with its high-spectral- resolution Infrared (IR) sounder, the Geostationary Interferometric Infrared Sounder (GIIRS). Following 15 years, the three-axis stabilized FY-4 series will offer full-disc coverage every 15 min or better (compared to 30 min of FY-2) and the option for more rapid regional and mesoscale observation modes. The Advanced Geosynchronous Radiation Imager (AGRI) has 14 spectral bands (increased from the 5 bands of FY-2) that are quantized with 12 bits per pixel (up from 10 bits for FY-2) and sampled at 1 km at nadir in the VISible (VIS), 2 km in the Near-Infrared (NIR), and 4 km in the remaining IR spectral bands (compared with 1.25 km for VIS, no NIR, and 5 km for IR of FY-2). FY-4 will improve most products of FY-2 and introduce many new products [such as atmospheric temperature and moisture profiles, atmospheric instability indices, Layer Precipitable Water vapor (LPW), rapid developing clouds, and others]. Products from FY4 series are expected to provide enhanced applications and services. These new products are compared with those of FY-2 in table 3.

Table 3 Products of FY-4 compared with FY-2

FY-2		FY-4	
Products	**Payloads**	**Products**	**Payloads**
Cloud detection	VISSR	Cloud masks	AGRI
Cloud classification	VISSR	Cloud type	AGRI
Total cloud amount	VISSR	Total cloud amount	AGRI
Precipitation estimation	VISSR	Rainfall rate/quantitative precipitation estimate	AGRI
Atmospheric motion vector	VISSR	Atmospheric motion vector	AGRI
Outgoing longwave radiation	VISSR	Outgoing longwave radiation	AGRI
Blackbody brightness temperature	VISSR	Blackbody brightness temperature	AGRI
Surface solar irradiance	VISSR	Surface solar irradiance	AGRI
Humidity product analyzed by cloud information	VISSR	Legacy vertical moisture profile	GIIRS
Total precipitable water	VISSR	Layer precipitable water	AGRI
Upper-tropospheric humidity	VISSR	Layer precipitable water	
Dust detection	VISSR	Aerosol detection (including smoke and dust)	AGRI
Sea surface temperature	VISSR	Sea surface temperature (skin)	AGRI
Snow cover	VISSR	Snow cover	AGRI
Land surface temperature	VISSR	Land surface (skin) temperature	AGRI
Cloud-top temperature	VISSR	Cloud-top temperature	AGRI
		Cloud-top height	AGRI
		Cloud-top pressure	AGRI
		Cloud optical depth	AGRI
		Cloud liquid water	AGRI
		Cloud particle size distribution	AGRI
		Cloud phase	AGRI
		Downward longwave radiation: surface	AGRI
		Upward longwave radiation: surface	AGRI
		Reflected shortwave radiation: top of atmosphere	AGRI
		Aerosol optical depth	AGRI
		Convective initiation	AGRI
		Fire/hot spot characterization	AGRI
		Fog detection	AGRI
		Land surface emissivity	AGRI
		Land surface temperature	AGRI
		Land surface albedo	AGRI
		Tropopause folding turbulence prediction	AGRI
		Legacy vertical temperature profile	GIIRS
		Ozone profile and total	GIIRS
		Atmosphere instability index	GIIRS
		Lightning detection	LMI
		Space and solar products	SEP

FY-4's AGRI will be operated in conjunction with GIIRS. FY-4's GIIRS is the first high-spectral-resolution advanced IR sounder onboard a geostationary weather satellite, complementing the advanced IR sounders in polar orbit. These include the Atmospheric Infrared Sounder (AIRS) onboard the National Aeronautics and Space Administration (NASA) Earth Observing System (EOS) Aqua platform, the Infrared Atmospheric Sounding Interferometer (IASI) onboard Europe's Meteorological Operational (MetOp) satellites, and the Cross-track Infrared Sounder (CrIS) onboard the Suomi National Polar-Orbiting Partnership. They have had a large positive impact in global and regional Numerical Weather Prediction (NWP) applications and climate research. However, severe weather warning in a pre-convective environment, nowcasting, and short-range forecasting require nearly continuous monitoring of the vertical temperature and moisture structure of the atmosphere on small spatial scales that only a geostationary advanced IR sounder can provide. The GIIRS will provide breakthrough measurements with the temporal, horizontal, and vertical resolution needed to resolve the quickly changing water vapor and temperature structures associated with severe weather events. GIIRS will be an unprecedented source of information on the dynamic and thermodynamic atmospheric fields necessary for improved nowcasting and NWP services. High-spectral-resolution IR measurements will also provide estimates of diurnal variations in tropospheric trace gases like ozone and carbon monoxide that will support forecasting of air quality and monitoring of atmospheric minor constituents.

The FY-4 GIIRS is one of the Group on Earth Observations (GEO) sounders planned by Global Earth Observation System of Systems (GEOSS) member states in response to the call from the World Meteorological Organization (WMO) for advanced sounders in the geostationary orbit. Another is the Infrared Sounder (IRS) planned by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) for the geosynchronous Meteosat Third Generation (MTG) satellite systems in the 2020 time frame and beyond. Together with the new generation of geostationary weather satellite systems being developed by other countries, FY-4 will become an important GEO component of the global Earth-observing system.

Overall, FY-4 represents an exciting expansion in Chinese geostationary remote sensing capabilities. FY-4A will be considered experimental and the subsequent satellites in the FY-4 series will be operational. Compared with the current operational FY-2 series, the FY-4 satellites are designed to have a longer operating lifetime. Table 4 summarizes some of the significant improvements in instrument performance expected from FY-4 compared with the current operational FY-2 series. For the FY-4 operational series of satellites, the main observation capabilities are similar to those of FY-4A, with some significant performance improvements. The AGRI channel number will be increased from 14 to 18 with IR spatial resolution of 2 km, and the full-disc temporal resolution will be enhanced from 15 to 5 min. GIIRS spectral and spatial resolutions will be increased to 0.625 cm^{-1} and 8 km, respectively. Lightning Mapping Imager (LMI) coverage will be enlarged to full disc. Space-monitoring instruments will be increased; for example, a solar X-ray and extreme ultraviolet imager will be on the following FY-4 series satellites.

3.3 FY2H Last Satellite in China's First Generation Geostationary Meteorological Satellite

The FY-2H was launched from Xichang Satellite Launch Center at 21:07 June 5 th. As the westernmost on-duty satellite in geostationary meteorological satellites layout of China, FY-2H can provide custom-made services for countries along "Belt and Road" territories, and data support for weather prediction and disaster prevention and mitigation.

FY-2 series satellites are the first generation geostationary meteorological satellites of China. China has launched eight FY-2 satellites since 1997. FY-2E, FY-2F, and FY-2G are still on orbit and operational. FY-2H was designed as the last operational satellite of the FY-2 series satellite. In response to a request from the World Meteorological Organization (WMO) and the Asia-Pacific Space Cooperation Organization (APSCO), the set-point position of FY-2H will be placed westward. State Administration of Science, Technology, and Industry for National Defense, China Meteorological Administration (CMA) and APSCO signed an intention of cooperation to finalize that FY-2H be moved westward by 7.5°, to 79°East (see Figure 6).

FY-2H, equipped with a scanning radiometer and space environment monitor, can supply dozens of remote sensing products like cloud images, clear sky atmospheric radiation, sand and dust, and Cloud Motion

Table 4 Advances of FY-4A compared with the current operational FY-2 series. SEM = Space Environment Monitor. SSP = subsatellite point

	FY-4A (experimental)	FY-4 (operational)	FY-2 (operational)
Stabilization	Three axis	Three axis	Spin
Designed life	7 years (designed life)	7 years (operation life)	4 years
Observation efficiency	85%	85%	5%
Observation mode	Imaging + sounding + lightning mapping	Imaging + sounding + lightning mapping	Imaging only
Main instruments	AGRI: 14 channels Resolution: 0.5–4 km Full disc: 15 min	AGRI: 18 channels Resolution: 0.5–2 km Full disc: 5 min	VISSR: 5 channels Resolution: 1.25–5 km Full disc: 30 min
	GIIRS: 913 channels SSP resolution: 16 km Spectral resolution: 0.8, 1.6 cm^{-1}	GIIRS: >1,500 channels SSP resolution: 8 km Spectral resolution: 0.625 cm^{-1}	—
	LMI Area coverage SSP resolution: 7.8 km	LMI Full-disc coverage SSP resolution: 7.8 km	—
	SEP High-energy particles Magnetic field	SEP High-energy particles, magnetic field, solar imager	SEM High-energy particles Solar X-ray fluxes

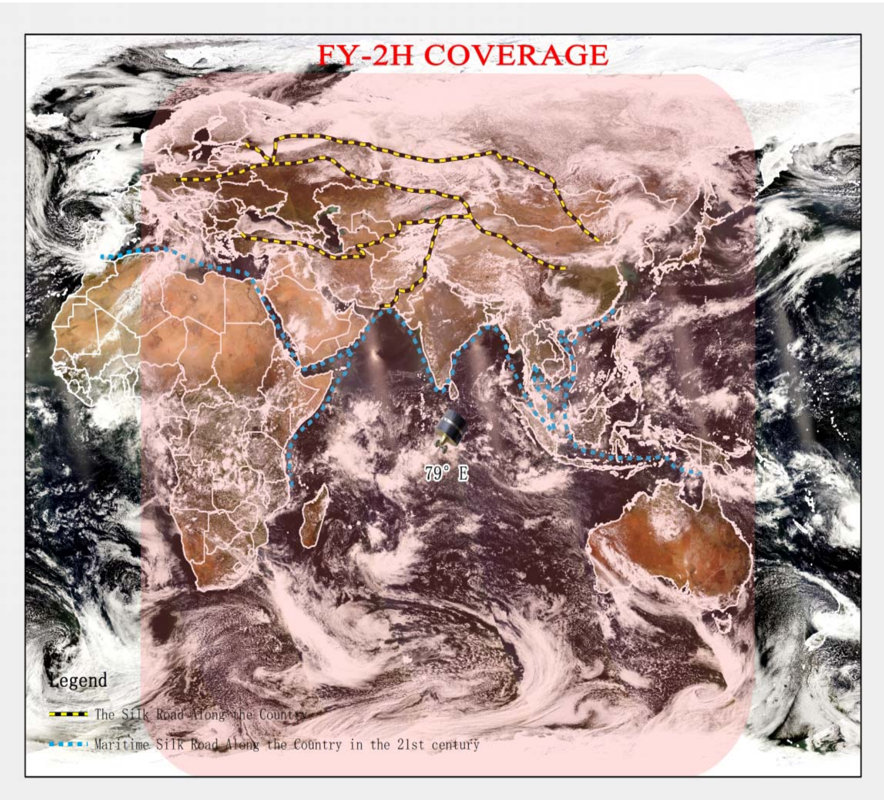

Fig. 6 Coverage of FY2H located at 79°E

Wind (CMW) for weather prediction, disaster early warning, and environmental monitoring, and enrich data sources of global NWP models.

To provide the 'Belt and Road' countries better weather services, CMA has announced 'Emergency Support Mechanism for International Users of Fengyun Meteorological Satellites in Disaster Prevention and Mitigation'. If countries along the Belt and Road, AP-SCO member states or SCO member states are gripped by disasters like typhoons, rainstorms, sandstorms, and forest or prairie fires, they can apply to activate dedicated observation by Fengyun satellites.

4. Summary

China has become one of the few countries who operationally maintain polar orbit and geostationary meteorological satellites. Chinese meteorological satellites are becoming an important component of the space- based global observing system.

The FY-3 series could provide greenhouse gas monitoring through a hyperspectral radiometer, sea wind de-tection through active microwave radar, and upper atmosphere sounding through limb view measurements and GNSS radio occultation measurements. It is believed that the FY-3 series not only benefit the nation of China, but they are also a valuable contribution to the international meteorological, hydrological, and environmental community.

With advanced imaging and sounding instruments on board FY-4A providing high temporal, spatial, and spectral resolution measurements, the benefit is expected to be large for severe weather monitoring, warning, and forecasting. With the first lightning imager on board the Chinese geostationary satellite, the added valuable lightning information is expected to significantly improve-warnings of severe storm hazards, convection precipitation, and lightning strikes. A primary use of the AGRI and GIIRS data will be to improve NWP through data assimilation of both radiances (AGRI, GIIRS) and L2 products (TPW, LPW, and AMVs from AGRI). Those data will be assimilated in the operational Global and Regional Assimilation and Prediction System (GRAPES) models and will also be distributed to the user community for operational applications. Assimilation of data and derived products from the AGRI, GIIRS, and LMI in both global and regional NWP models are expected to show valuable improvement in forecast skill. FY-4A will also enhance space weather monitoring and warning. Together with the new generation of geostationary weather satellites planned by the international satellite community, the FY-4 series will become an important geostationary component of the global Earth-observing system.

Current Fengyun data delivery services include the web-based services, FTP push service, FTP pull service, manual service, and CMACAST service. Users can access the data through the webpage (http://FY3.satellite.cma.gov.cn) after a quick and free registration. It is believed that the FY-3 series satellites not only benefit the nation of China, but also make a valuable contribution to the international meteorological, hydrological, and environmental community.

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