The Digital Earth and Meteorological Satellite Program of China

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1. Introduction

The concept of digital earth broden the view of the earth sciences and guided the technical dev-elopment of the earth sciences for the future. The difinition of the earth includes the rock sp-here, biospher, hydrological sphere, atm-osphere, and outsphere. From global point of view, most of the digitals which composed of the digital earth will mainly come from various kinds of satellite platforms. Among them, the meteorological satellite, with inc-reasing pow-erful instrumentation, will play imp-ortant role in digital earth.

Meteorological satellites have become an irreplaceable weather and ocean observing tool in China. These satellites are monitoring major natural disasters and improving the efficiency of many sectors of our national economy. Therefore, me-teorological satellite has been regarded as a kind of applied satellite with notable social and economic benefit among man-made satellites. It is not feasible nowadays to ignore the derived data from mete-orological satellite in the field of meteorology, hydr-ology, agriculture as well as disaster monitoring in China, such a big agricultural and developing cou-ntry. For this reason, China is making her unre-mitting efforts on building up the meteorological sat-ellite system and data application system.

The meteorological satellite program of China consists of two major systems: Polar orbiting and geostationary series. The main objectives of the program are to establish, with combination of polar and geostationary orbits, a comprehensive operational meteorological satellite system as well as the ground monitoring and application data system around the turn of the century, in order to meet the need on various aspects in China, and enhance the ability to participate international collaboration. The Ministry of Aerospace of China takes the responsibility for the space segment, while the China Meteorological Administration is in charge of the ground segment.

In China, meteorological satellites are named simply as Feng-Yun series, abbreviated as FY-series. The Chinese words Feng-Yun in English standards for "Winds and Clouds". We use the FY-odd number ,i.e. FY-1,FY-3, etc. to name the polar orbiting satellite series, and FY-even number, i.e.FY-2, FY-4, etc. for geostationary series.

2. The China's First Generation of Polar Orbiting Meteorological Satellites: FY-1

According to the present plan, China's first generation of polar orbiting meteorological satellite system, FY-1, will consist of four satellites, as well as the corresponding ground data acquisition and processing systems. The four FY-1 satellites are devided into two batches, that is the first batch inc-luding FY-1A and FY-1B satellites, and the second batch consisting of FY-1C and FY-1D satellites.

2.1. The FY-1A and FY-1B

With the increasing awareness of the importance of satellite meteorology in 1960's, China has initiated her first polar orbiting meteorological satellite project, FY-1, in 1977. The FY-1A and FY-1B were designed and manufactured by the Ministry of Aerospace of China according to the requirement specified by China Meteorological Administration (CMA). The satellite is a hexahedron of 1.4×1.4×1.2(in height) and the weight is 750 kg. The two solar cell arrays mounted on both sides of the main body make the total length of the satellite 8.6 meters. The attitude control of the satellite is three-axis stabilized with a precision of no less than 1 degree in all three axis. FY-1A and FY-1B operated in a sun-synchronous orbit at an altitude of 901 km with an orbital period of 102.86 minutes. The inclination angle is 98.9^{o} and the eccentricity is less than 0.005. Table 1 gives the main orbit parameters of the FY-1A and FY-1B satellites

The main meteorological payload on board FY-1A and FY-1B satellites are five channel Visible and Infrared Radiometers, similar to AVHRR instrument but with different channel wavelengths. Table 2 gives the channel characteristics of the radiometer on board FY-1A and FY-1B satellites The FY-1 observation data are disseminated in three modes: High Resolution Picture Transmission

Satellite	FY-1A	FY-1B
Launch date	September 9,1988	September 3, 1990
Orbit	Sun-synchronous	Sun-synchronous
Altitude (km)	901	901
Period (minutes)	102.86	102.86
Inclination (degrees)	99.0	98.9
Eccentricity	<0.005	<0.005
Descending Node(LST)	03:30	07:50
Attitude Control	Three-axis stabilized	Three-axis stabilized

Table 1. Orbit parameters of FY-1A/B Meteorological satellites

Channel	Wavelength(μm)	Primary Use
1	0.58-0.68	Cloud and surface image, vegetation
2	0.725-1.1	Cloud and surface image, vegetation
3	0.48-0.53	Ocean color
4	0.53-0.58	Ocean color
5	10.5-12.5	Diurnal cloud and surface image, SST

Table 2. The channel characteristics of radiometers onboard FY-1A and FY-1B

(HRPT), Automatic Picture Transmission (APT), and Delayed Picture Transmission (DPT). For HRPT and APT, direct readout services are provided during satellite operations with data format compatible with NOAA satellites. The DPT data are cloud images from selected areas over the world for domestic use only.

The ground segment of FY-1 consists of three ground stations located in Beijing, Guanzhou and Urumuqi respectively and a Data Processing Center (DPC) at National Satellite Meteorological Center in Beijing. The data received at the ground stations are relayed in real time to the Beijing DPC for processing, distributing, and archiving. Derived products from the DPC include cloud image masaics in a variety of projections, meteorological parameters such as sea surface temperature, clout top temperature and total water vapor; regional environmental parameters such as vegetation index, snow cover, sea ice, land cover, etc. All raw data and products are archived on digital tapes. Images are broadcast via TV to the public.

2.2. The FY-1C and FY-1D

China has launched FY-1C on May 10, 1999 and will FY-1D in the year 2001. These two satellites are developed on the basis of FY-1A and FY-1B. Besides the efforts to improve the reliability of satellites there are some changes on imaging instruments and data transmission as follows:

(1) The channel numbers of the Visible and Infrared Radiometers are increased to ten channels, which enables the more powerful observations to the land and oceans.

(2) The on board data storage capacity is increased to 300 minutes (60 minutes on FY-1A/B). This enables China to receive global coverage data of four selected channels with reduced resolution (4 km) for one time each day (defined as Delayed Global Picture Transmission, DGPT), as well as 20 minutes orbit observation data of ten channels with original resolution at any region of the world (defined as Delayed Local Picture Transmission, DLPT).

(3) The FY-1C and FY-1D High Resolution Picture Transmission will be also very similar to NOAA/HRPT, except the data transmission rate. It is considered that the system that receives and process NOAA/HRPT nowadays can receive and process the FY-1 data with updating as few as possible. The data transmission rate is double that of current NOAA/HRPT, i.e., the data transmission is 1.3308 Mbps. The transmission modulation is PSK and bit format is split phase.

(4) The design life of FY-1C/D is for two years.

(5) There is no APT in FY-1C and FY-1D.

The instantaneous field of view of the radiometer is 1.2 mrad and the resolution at the satellite subpoint is 1.1 km. The scan rate is still 6 lines/sec and the total pixels of each scan line are 2048. The channel features of the main payload on FY-1C and FY-1D: the ten-channel Visible and Infrared Radiometers are indicated in table 3.

Channe l	Wavelength(μm)	Primary Use
1	0.58-0.68	Daytime cloud, ice and snow, vegetation
2	0.84-0.89	Daytime cloud, vegetation
3	3.55-3.95	Heat source, night cloud
4	103.-11.3	SST, day/night cloud
5	11.5-12.5	SST, day/night cloud
6	1.58-1.64	Soil moisture, ice/snow distinguishing
7	0.43-0.48	Ocean color
8	0.48-0.53	Ocean color
9	0.53-0.58	Ocean color
10	0.90-0.985	Water vapor

Table 3. The channel characteristics of radiometers onboard FY-1C and FY-1D

3. China's Geostationary Meteorological Satell-ites

3.1. General

China has launched its first generation of geos-tationary meteorological satellite FY-2 with the Long March-3 rocket from the Xi Chang Satellite Launching Center on June 10, 1997. The satellite is located in the equator of 105^{o}E. FY-2 satellite data is open for international users, therefore the satellite data can be shared with other countries. User stations covered by FY-2 can receive S-VISSR high resolution digital data and WEFAX low resolution analog data.

3.2. FY-2 Satellite and Radiometer

FY-2 satellite consists of the following subsystems: remote sensing subsystem, i.e. the, the data transmission and broadcasting subsystem, data collection subsystem, telemetry and command subsystems. antenna subsystem, attitude and orbit control subsystem, power subsystem, thermal cont-rol and apogee motor subsystem etc.

3.2.1. Function of Satellite

FY-2 meteorological satellite has the following functions:

- Obtaining visible, infrared and water vapor cloud images by a radiometer on board satellite. Sea surface temperature, cloud analysis chart, cloud parameters and wind vector can be derived from these data.
- Collecting and transmitting observed data from widely dispersed data collection platforms.
- Broadcasting S-VISSR data, WEFAX and S-FAX or processed cloud images
- Monitoring space environmental from satellite.

Dimensions	Diameter Height	2.1 m 1.6 m (cylinder)
Mass	Launch On Station	1200 kg 520 kg
Life	Design life	3 years
Orbit	Geostationary	located at 105^{o}E
Attitude	Spin-stabilized	Spin rate :100±1 rpm
Launch Vehicle	Long March-3	

Table 4.The FY-2 Satellite Specifications

	Visible	Infrared	Water Vapor
Wavelength	0.5-1.05 μm	10.5-12.5μm	6.2-7.6μm
Resolution	1.25 Km	5 Km	5 Km
FOV	35 μrad	140μrad	140μrad
Scan Line	2500×4	2500	2500
Detector	Si-photo-diode	HgCdTe	HgCdTe
Noise Performance	S/N=6.5 @albedo=2.5% S/N=43 @albedo=95%	NEDT=0.5-0.65k @300k	NEDT=1k @300K
Quantification Precision	6 bits	8 bits	8 bits

Scan step angle	140 μrad (N-S scanning)		
Frame time	30 minutes		

Table 5. Major Characteristics of VISSR

3.2.2. Visible and Infrared Spin Scan Radiometer

The major payload of FY-2 meteorological satellite is Visible and Infrared Spin Scan Radiometer (VISSR) . The characteristics of the instrument are shown in Table 5.

The VISSR performs Earth and cloud observations from space. Visible, infrared and water vapor images of he Earth and its clouds are derived from the VISSR.

During a scanning, the optical telescope collects visible, infrared and water energies from the Earth and clouds, and then focuses them on the focal plane with primary and secondary mirrors. Visible fiber optics and infrared relay optics system relay energies from the telescope focal plane to visible, infrared and water vapor detectors. Si detectors convert visible light into visible analog signals and HgCdTe detectors cooled by radiation coolers convert the Earth's radiation into infrared analog signals. The S-VISSR outputs are fed to a VISSR Digital Multiplexer (VDM) unit with redundancy.

- Visible Channel (0.55-1.05 μm)

Four Si detectors and redundant sets simultaneously convert visible light into four-channel visible analog signals of 1.25 km resolution at the sub-satellite point (SSP) with one west-east scanning.

- Infrared Channel (10.5-12.5 μm)

High sensitive HgCdTe detectors with redundancy, which are kept at a temperature of 100K by the radiation cooler, convert Earth radiation into infrared analog signals with 5 km resolution images at SSP

- Water Vapor Channel(6.3-7.6 μm)

Extremely sensitive HgCdTe detectors with redundancy, which are kept at a temperature of 100K by the radiation cooler, convert Earth radiation into infrared analog signals with 5 km resolution images at SSP

- Imaging

A complete $20^{o}\times20^{o}$ scan covering the full Earth disk can be accomplished every 30 minutes by means of combination of satellite spin motion (100 rpm from west-east) and step action of the scan mirror (2500 steps from north to south). It takes 25 minutes for taking picture, 2.5 minutes for mirror retrace, and 2.5 minutes for VISSR stabilization.

3.3 FY-2 Ground Application Facilities

The FY-2 program ground system consists of the following: A Command and Data Acquisition Station (CDAS), a Data Process Center (DPC), a Satellite Operation Control Center (SOCC), Ranging Stations (one primary station, three secondary stations including one in Australia), widely dispersed Data Collection Platforms (DCP), Medium-scale Data Utilization Stations (MDUS) and Small-scale Data Utilization Stations (SDUS), and a Ground Communication system etc..

The tasks of FY-2 ground system are as follows:

- Receive day and night cloud, water image data from VISSR
- Produce a variety of images and products after processing by DPC
- Receive, edit, and distribute meteorological, oceanographic, hydrological observation data collected by DCP
- Retransmit stretched VISSR data, LR-FAX, and WEFAX.
- Extract the information of solar protons and other particles from telemetry data stream and distribute them to users
- Satellite operation management and control, VISSR scan mode selection and satellite status monitoring.

3.4. Data Broadcasting of FY-2

One of the major functions of FY-2 system is to broadcast data including S-VISSR, WEFAX and S-FAX data via FY-2 satellite. The S-VISSR data are transmitted to Medium-scale data Utilization Station (MDUS) through the FY-2 during the VISSR observation. WEFAX and S-FAX data are retransmitted to Small-scale Data Utilization Station (SDUS). The S-FAX of FY-2 is only for domestic users.

3.4.1. Transmission Characteristics of the FY-2 S-VISSR

The S-VISSR data are the digital image data originated by VISSR on board and the stretched on CDAS in time. Therefore, the transmission rate is reduced. The S-VISSR data are retransmitted to MDUS via the FY-2 during the VISSR observation. Since the signal characteristics of FY-2 S-VISSR data are as the same as GMS S-VISSR data except frequency, the user stations now receiving GMS S-VISSR data can receive FY-2 S-VISSR data by changing the antenna pointing and frequency of receiver local oscillator.

3.4.2. Transmission of the FY-2 WEFAX

The WEFAX is disseminated to SDUS users via FY-2 satellite. The WEFAX transmission is in the format that is completely compatible with those of other geostationary meteorological satellites. The WEFAX is composed of gray scales, marks, annotation and earth image. The annotation signal is inserted at the head of the picture, so as to recognize the image information automatically. The earth images contain latitude-longitude grids and coastline bases of the prediction of the satellite's orbit and attitude.

3.5. The FY-2 Data Collection System

There are 133 data Collection Platforms (DCP) channels in FY-2 system, including 100 regional DCP channels and 33 international DCP channels, which can collect data from a wide variety of platforms. The regional DCPs are stationary DCPs that installed on buoys, isolated islands, rivers, mountains or ships (regional) for meteorology, oceanography, hydrology, and other purposes. They are fixed within the coverage of the FY-2 satellite. This is a self-timing DCP, which can transmit messages automatically on schedule time. The collected data are edited at the NSMC and distributed to the user via GTS. NSMC will perform a monitoring service and consult the user of the difficulties regarding DCPs. FY-2 also carries a Space Environment Monitor for monitoring high-energy particles at the satellite environment.

4. The Advantages of Meteorological Satellites and Their Role in Digital Earth

There are many advantages of meteorological satellites for proving the key data for the digital earth, therefore the data will play important role in the digital earth..

4.1 Large Areas and Frequent Observations

Meteorological satellite can observe the Earth in quite high time frequency, and may be more im-portant, in global and large scales. For example, for geostationary meteorological satellites, hourly and half-hourly Earth images can be obtained oper-ationally with the coverage of 1/3 the whole earth. For some special case, the image intervals can be as short as several seconds. For polar mete-orological satellites, the observational frequency can be at least four times per day and with global coverage. These key observational data can really make a live and fast-changed Digital Earth for the whole global or for large scales.

4.2 Multi-Spectral images.

The polar meteorological satellites with even-increasing powerful payloads enable the obs-ervations multi-spectral and moderate spectral res-olutions. The spectral bands now covers ultraviolet, visible, near infrared, thermal infrared, and mic-rowave. It is quite powerful for classifying of the su-rface type characteristics of the earth and the phe-nomenon of the atmosphere.

4.3 The Stereo Images of the Earth.

The payloads onboard the meteorological satellites can not only observe the surface of the earth, but also has the powerful capability to observe the earth atmosphere. These observations include three dimensional thermal structures, moisture structures, total ozone and ozone profiles, cloud distributions, aerosol, rainfall and snowfall, as well as other trace gases. The atmosphere and the earth surfaces interact each other and these data are necessary for us to build up the stereo digital earth.

4.4 Moderate Spatial Resolutions

The spatial resolution of the meteorological satellites increased rapidly in last decade and will improve further in the following years. For example, with the launch of the MODIS onboard the EOS sa-tellite series, the spatial resolutions for some cha-nnels is as high as 250 meters. The spatial reso-lution for the infrared channels can be improved to 400 meters as considered in NPOESS program. For large areas and especially for global scale, this re-solution is pretty good and quite sufficient for some earth parameters.

5. Future Plans of Chinese Meteorological Satell-ites and Summary

Now China is planning the second generation of polar and geostationary meteorological satellites. Meanwhile more and more foreign meteorolo-gical/environmental satellites, such as EOS/IEOS, METOP, ENVIRSAT, etc., can be received in the following years. These satellite data will rich the database of the digital earth and make the digital earth fast upgraded with the latest information and digital. In one word, meteorological satellite will make great contribution to the digital earth era.

The above presented Chinese Fengyun meteo-rological satellite series, with the combination of polar orbiting and geostationary meteorological satellites, consider the contribution of China to the global environmental satellite system and digital earth. China will make the basic digital earth pro-ducts from Chinese meteorological satellites ava-ilable to support the digital program, and is willing to carry out international collaboration in this field.