CGMS-XXXII
WMO WP-26
Prepared by WMO
Agenda item: D.1

STATUS OF THE SPACE-BASED COMPONENT OF THE GLOBAL OBSERVING SYSTEM (GOS)

(Submitted by WMO)

Summary and purpose of document

The document contains, as an appendix, a report prepared by a WMO Consultant, Dr. Bizzarri. The appendix is intended to:

- provide a framework for structuring the information provided by CGMS Members on satellite programmes, instrument characteristics and radio frequency usage in order to facilitate information update in such a way to allow easy comparisons and assess the degree of compliance of the GOS evolution with WMO requirements;
- perform an assessment of the GOS status with respect to WMO requirements in terms of both observing coverage and data quality, at the nominal date of December 2003 and as projected in the near-future until 2006.

The current issue does not include R&D satellites and instruments, pending availability of information for inclusion in the next issue that will have a nominal date of December 2004.

ACTIONS PROPOSED

1. CGMS to note the status of current and planned satellites of GOS at the nominal date of 31 December 2003, i.e. soon after CGMS XXXI.
2. CGMS Members to carefully check the information reported in this first issue and, specifically, contribute to resolve doubtful areas and to provide missing information (note that missing information is indicated in yellow), preferably in advance of CGMS XXXII so as to make possible a last-minute updated version. To this purpose, CGMS Members are recommended to designate a contact point to directly interact with Dr. Bizzarri at bibizzar@tin.it .
3. CGMS to note the sections reporting the analysis of compliance of GOS with WMO requirements at end-2003 and 2006 in terms of observation coverage (Sections 2.8 and 3.8) and instruments performance (Sections 2.9 and 3.9).
4. R&D CGMS Members to provide appropriate satellites and instruments information to be included in the next issue of the report at the nominal date of 31 December 2004.

Appendix: "Status of the space-based component of the Global Observing System (GOS) at the nominal date of 31 December 2003" - Report to WMO by Dr. Bizzarro Bizzarri.

STATUS OF THE SPACE-BASED COMPONENT OF THE GLOBAL OBSERVING SYSTEM (GOS) AT THE NOMINAL DATE OF 31 DECEMBER 2003

REPORT TO WMO
BY DR. BIZZARRO BIZZARRI

This document collects essential information on satellites and instruments that form the space-based component of the GOS at the nominal date of issue. It is compiled on the basis of:

- information provided by satellite operators members of CGMS at their annual meetings (last: CGMS XXXI, Ascona, Switzerland, 10-13 November 2003);
- the WMO/CEOS Database on User requirements and space capabilities and a number of WMO Technical Reports, specifically No. 411;
- extensive search on the Web for missing information, details and latest updates;
- books and personal notes, especially for the historical elements.

The structure of the document is such that it will provide, when updated on an at least annual basis, a short historical background on the various programmes, a slowly-evolving framework on current and developing systems/instruments and a more evolutionary framework for input of the latest information on systems/instruments that are in their definition phase.

An effort has been made to provide template-like information in order to ensure compliance with homogeneity and completeness. This should facilitate comparisons of programmatic elements and performances. The purpose is to provide an available and simple tool to check to which extent the requirements of WMO Programmes for Earth observations coverage and quality are fulfilled.

The following systems have been considered:

- the constellation of operational meteorological geostationary satellites;
- the constellation of operational meteorological sunsynchronous satellites.

R&D programmes have not been included in this issue, pending the availability of appropriate information.

Summary tables and graphics are provided showing the comprehensive Earth coverage service and the degree of uniformity for data quality. This represents the first example of utilisation of the effort to consolidate into a single document information related to the space systems comprising the space-based component of the GOS. The second example of possible utilisation is in the form of a guideline to CGMS members to facilitate information updating, particularly on instruments and on the radio frequencies used for data transmission to the ground.

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1. The space-based component of the Global Observing System

The ***Global Observing System (GOS)*** is coordinated by the WMO in support of all its programmes:

- WWW (World Weather Watch)
- WCP (World Climate Programme), including:
  - World Climate Data and Monitoring Programme
  - World Climate Applications and Services Programme
  - World Climate Impact Assessment and Response Strategies Programme
  - World Climate Research Programme
  - Global Climate Observing System
- AREP (Atmospheric Research and Environment Programme), including:
  - Global Atmosphere Watch
  - World Weather Research Programme
  - Tropical Meteorology Research Programme
  - Physics and Chemistry of Clouds and Weather Modification Research Programme
- AMP (Applications of Meteorology Programme), including:
  - Agricultural Meteorology Programme
  - Aeronautical Meteorology Programme
  - Marine Meteorology and Associated Oceanographic Activities Programme
  - Public Weather Services Programme
- HWRP (Hydrology and Water Resources Programme), including:
  - Operational Hydrology Programme - Basic Systems
  - Operational Hydrology Programme - Applications and Environment
  - Programme on Water-related Issues
- Education and Training Programme
- Technical Cooperation Programme
- Regional Programme.

The GOS is composed of surface-based systems and space-based systems. The space-based component of the GOS is implemented and managed by agencies linked to national meteorological services as well as two intergovernmental organizations, EUMETSAT and ESA. The ***Coordination Group for Meteorological Satellites (CGMS)*** is a forum for coordination of the space-based systems. CGMS Members whose primary focus is operational meteorological satellite systems are:

- EUMETSAT, on behalf of 18 European Member States and 7 Cooperating States
- NOAA (National Oceanic and Atmospheric Administration)
- ROSHYDROMET (Hydro-Meteorological Service of the Russian Federation)
- IMD (India Meteorological Department)
- JMA (Japan Meteorological Agency)
- CMA (China Meteorological Department)
- WMO (World Meteorological Organization)
- IOC (Intergovernmental Oceanographic Commission) of UNESCO.

CGMS now includes several R&D space agencies, either as supportive to their corresponding operationally-oriented agency or as a full CGMS member. They are:

- ESA (European Space Agency) (full CGMS Member)
- NASA (National Aeronautics and Space Administration) (full CGMS Member)
- ROSAVIAKOSMOS (Russian Space Agency) (full CGMS Member)
- ISRO (India Space Research Organisation)
- JAXA (Japan Aerospace Exploration Agency), formerly NASDA(full CGMS Member)
- CNSA (China National Space Agency)
- CNES (Centre National d'Etudes Spatiales) (full CGMS Member).

The space-based component of the GOS includes:

- operational meteorological satellites in geostationary orbit
- operational meteorological satellites in sunsynchronous orbit
- a number of R&D satellites, or instruments carried by R&D satellites or R&D instruments carried on an operational satellite, that comply with certain basic WMO criteria such as:
  - relevance to WMO programmes
  - limited service continuity, though, in some cases, within an evolutionary system/instrument environment
  - data access on a non-discriminatory basis as defined by the R&D agency and according to modes standardised to the maximum extent possible
  - a formal statement made to WMO describing the commitment.

The ***WMO Space Programme*** agreed upon by the Fourteenth WMO Meteorological Congress in May, 2003 and entered into force on 1 January 2004, will monitor the space-based component of the GOS and, specifically, will monitor the progressive extension from the traditional operational "core" to a wider system inclusive of contributions from R&D satellites as well as the transition of appropriate R&D missions and instruments into operational services.

The ***operational meteorological geostationary satellite system*** includes the following series:

- the European Meteosat series
- the United States of America's GOES series
- the Japanese GMS series being replaced by the MTSAT series
- the Russian GOMS series
- the Chinese FY-2 to be replaced by the FY-4 series
- the Indian INSAT series and the Kalpana (formerly MetSat) series (although not part of the GOS at this time).

The ***operational meteorological sunsynchronous satellite system*** includes the following series:

- the United States of America's POES series, supported by DMSP, to converge into the NPOESS series
- the European MetOp series (in preparation)
- the Russian Meteor series
- the Chinese FY-1 series to be replaced by the FY-3 series.

The integration of ***R&D satellites*** into the GOS is formally established and coordinated under the Commission for Basic Systems (CBS) with guidance for the WMO Space Programme by the "WMO Consultative Meetings on High Level Policy on Satellite Matters" (last session: CM-4, Geneva 26-27 January 2004) and with CBS having lead technical commission responsibility for the Space Programme. However, in this report, R&D satellites have not been included, waiting for appropriate information to be entered.

In this Report, the following information is provided, for each satellite programme:

- a short description of the programme, inclusive of some historical background
- the status of the currently operational satellites
- a description of the next satellites in the series
- the radio frequency plans for data transmission to the ground
- tables containing instrument information for currently operational and consolidated planned payloads (in ***Appendix***).

The basic imagery and sounding missions are described with some detail, whereas other missions are mentioned only very briefly.

In addition, the degree of compliance of the operational meteorological satellite constellation with WMO requirements will be assessed in respect of the following features:

- coverage from the geostationary orbit (requirement: six satellites regularly spaced)
- coverage from the sunsynchronous orbits (requirement: four satellites optimally spaced)
- suitability of the instrumentation to provide information of comparable quality across systems.

Fig. 1.1 and ***Fig.1.2*** show the coverage that would be provided by the space-based component of the GOS if implemented by (Fig. 1.1) six geostationary satellites 60-degrees spaced, at any time, and (Fig. 1.2) four sunsynchronous satellites at equally-spaced Local Solar Time (LST), in three hours. The figures refer to instruments with day-and-night capability (i.e. operating in IR or MW), useful field of view of 60° geocentric angle from GEO, and various swaths from LEO: typical of VIS/IR imagers (2900 km), of sounders (2200 km) and of conical scanning microwave radiometers (1400 km).

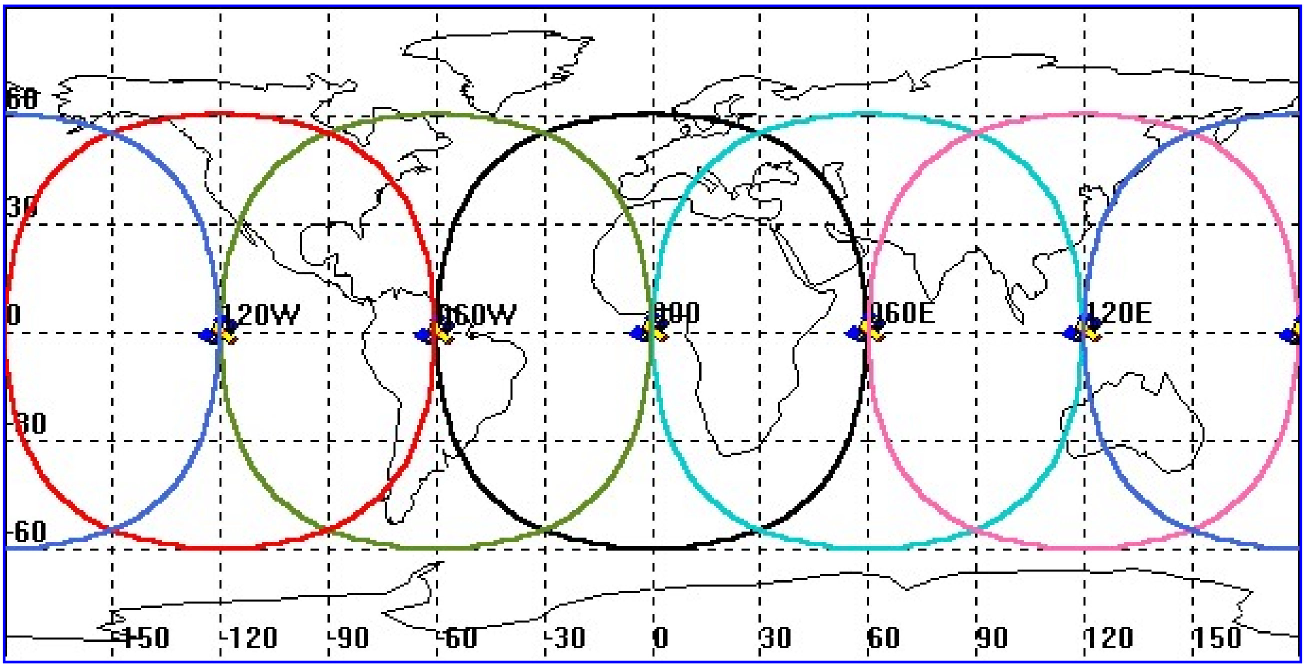
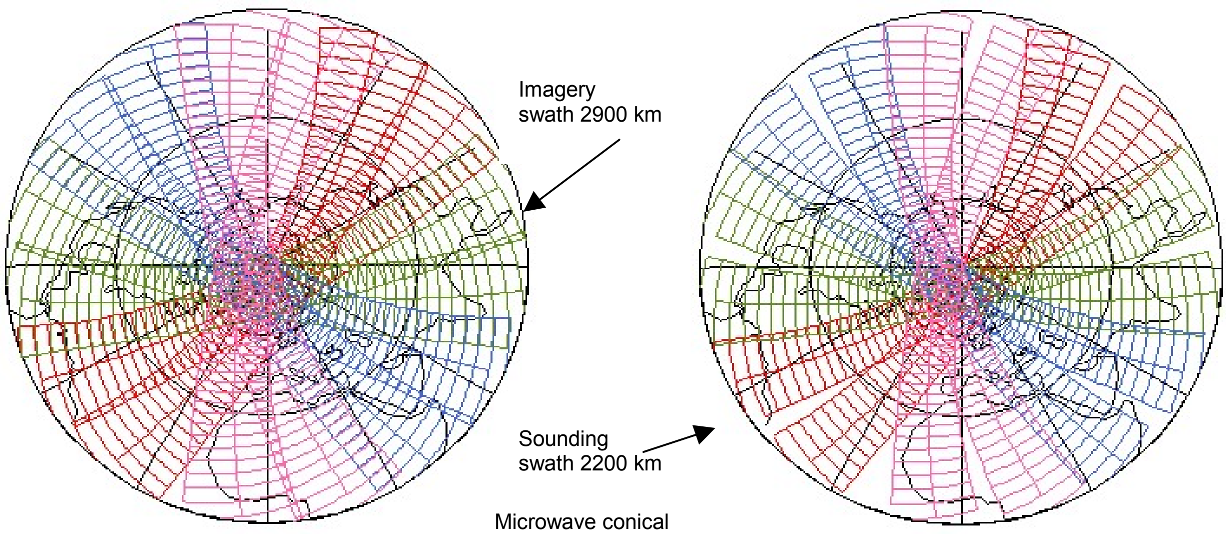


Fig. 1.1 - Coverage from six regularly-space geostationary satellites. The circles subtend a geocentric angle of 60°, considered the practical limit for quantitative observations (images extend beyond). All latitudes between 55°S and 55°N are covered.



Microwave conical
swath 1400 km

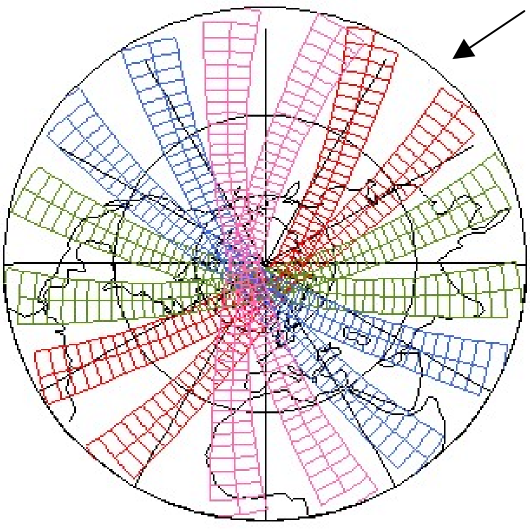


Fig. 1.2 - Coverage from four sunsynchronous satellites of height 833 km and LST regularly spaced at 00:30, 03:30, 06:30 and 09:30 at the descending equatorial node. The figure refers to a time window of 3 h and 23 min (to capture two full orbits of each satellite) centred on 12 UT. Three typical swaths are considered: upper-left 2900 km for the imagery mission; upper-right 2200 km for the sounding mission; bottom-left 1400 km for microwave conical scanners. 3-hourly global coverage is provided for the imagery mission down to the equator and for the sounding mission at latitudes above 30 degrees. For microwave conical scanners global coverage in 3 hours requires 8 satellites.

Geostationary satellites

1.1 Generalities

At the time of the First GARP Global Experiment (FGGE, 1979-80) the WMO requirement for geostationary satellites was four satellites, regularly spaced by about 90° around the equator. The coverage was varying from a maximum of over 60° latitude at the longitude of stationarity to a minimum of 45° latitude in between the stationarity points of two satellites. In the early 90's the requirement was increased to five satellites spaced 72° to rise the minimum coverage to about 52° latitude. In 2002 the requirement has been increased to six satellites optimally spaced, that extends global coverage to a minimum of 55° latitude. That also ensures that sufficient contingency margins exist in case one of the satellites is defective, waiting for the replacement.

The mission of geostationary satellites is, as a core:

- to provide cloud imagery at 30 min intervals for the purpose of nowcasting
- to derive wind vectors by tracking cloud or water vapour features, for the purpose of NWP.

Several satellites provide more than this. Some provide more frequent images, some temperature and humidity profiles by IR radiometry, some Earth radiation budget observation. In addition, several products are derived by image processing, specifically surface parameters and precipitation estimates. The Extraordinary Session of CBS in Cairns, Australia, 4-12 December 2002, solicited Members to strengthen the sounding mission from GEO in the 2015 framework by moving from radiometric to spectrometric techniques to improve the profile's vertical resolution.

1.2 The Meteosat programme

The Meteosat programme is designed to be fully redundant, with the nominal operational satellite stationary over 0° and a standby over about 10°W. The programme evolved through three phases:

- ***Meteosat Pre-operational Programme*** (Meteosat-1/2/3)
- ***Meteosat Operational Programme (MOP)*** (Meteosat-4/5/6/7, the last also known as Meteosat Transition Programme or MTP)
- ***Meteosat Second Generation (MSG)*** (Meteosat-8 to be followed by 9/10/11).

All Meteosat satellites, both of the first series (***Fig. 2.2.1***) and MSG (***Fig. 2.2.2***), are spin-stabilised. ***Table 2.2.1*** summarises the chronology of the Meteosat programme.

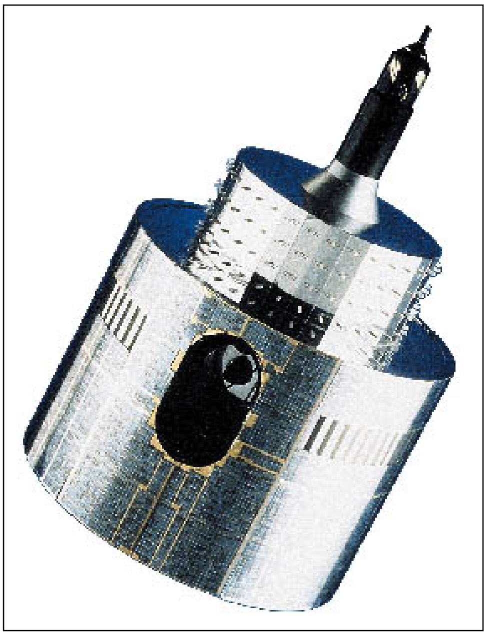


Fig. 2.2.1 - View of Meteosat/MOP.

Fig. 2.2.2 – View of Meteosat/MSG.

Table 2.2.1 - Chronology of the Meteosat programme *(in bolt the satellites active at end 2003)*

Satellite	Launch	End of service	Position	Status (Dec 2003)	Instruments
Meteosat-1	23 Nov 1977	24 Nov 1979		Inactive	MVIRI, DCS
Meteosat-2	19 Jun 1981	2 Dec 1991		Inactive	MVIRI, DCS
Meteosat-3	15 Jun 1988	22 Nov 1995		Inactive	MVIRI, DCS
Meteosat-4	6 Mar 1989	8 Nov 1995		Inactive	MVIRI, DCS
Meteosat-5	**2 Mar 1991**	**expected ≥ 2004**	**63°E**	**Operational**	**MVIRI, DCS**
Meteosat-6	**20 Nov 1993**	**expected ≥ 2005**	**10°E**	**Backup (+ rapid scan)**	**MVIRI, DCS**
Meteosat-7	**3 Sep 1997**	**expected ≥ 2005**	**0°**	**Operational**	**MVIRI, DCS**
Meteosat-8 (MSG-1)	**28 Aug 2002**	**expected ≥ 2009**	**3.4°W**	**Just commissioned**	**SEVIRI, GERB, DCS, GEOSAR**
Meteosat-9	2005	expected ≥ 2012		Being integrated	**SEVIRI, GERB, DCS, GEOSAR**
Meteosat-10	2009	expected ≥ 2016		Being built	**SEVIRI, GERB, DCS, GEOSAR**
Meteosat-11	2011	expected ≥ 2018		Planned	**SEVIRI, GERB, DCS, GEOSAR**
MTG	2015	expected ≥ 2020		Being defined	Being defined

At the end of 2003 three satellites of the MOP series are still active (Meteosat 5, 6 and 7) and the commissioning of the prototype of the MSG series (MSG-1 = Meteosat-8) has just completed.

Meteosat-5

Launched in March 1991, Meteosat-5 was moved in July 1998 over the longitude of 63°E to support INDOEX (Indian Ocean Experiment). Since then it still continues to provide an operational service. It could in principle be operated through 2004 and beyond.

Metosat-6

Launched in November 1993, Meteosat-6 was moved in August 2000 over the longitude of 9°W to support MAP (Mesoscale Alpine Programme) by providing frequent imagery (at 10 min intervals) over a limited area. Since then, the rapid scan service is being continued. It also constitutes the backup of Meteosat-7, the nominal operational satellite. After the launch of MSG-1, in October 2002 it has been moved over 10°E. It could in principle be operated through 2005 and beyond.

Meteosat-7

Previously known as MTP (Meteosat Transition Programme), Meteosat-7, launched in September 1997, is the nominal operational satellite over the 0° longitude. It will be operated till at least the whole 2005 in parallel with MSG-1 to ensure a smooth transition between the two satellite generations.

Payload of Meteosat 1 to 7

All Meteosat satellites till Meteosat-7 are equipped with a single sensor:

- ***MVIRI (Meteosat Visible and Infra Red Imager)***, a 3-channel VIS/IR radiometer with 5 km resolution in two IR channels and 2.5 km in VIS; image cycle 30 min (or less, over a progressively limited area, as with Meteosat-6). See the instrument sheet in Appendix.
- ***Data Collection Service (DCS)*** to relay *in situ* observations from Data Collection Platforms (DCP) - Main features:
  - uplink: frequencies 402.0-402.1 MHz for 33 international channels, 402.1-402.2 MHz for 33 regional channels; bandwidth 3.0 kHz each, data rate 100 kbps, polarisation right-hand circular.

Data transmission from Meteosat 1 to 7

Image data are transmitted in real time to the:

- Primary Ground Station (PGS). Main transmission characteristics:
  - frequency 1686.833 MHz, bandwidth ...... MHz, linear polarisation, data rate 333 kbps.

After pre-processing, data are re-transmitted to user stations in S-band. There are two services:

- ***HRIDS, High Resolution Image Dissemination Service***, for digital images
- ***WEFAX Dissemination Service***, for analogue images.

Correspondingly, there are two types of user stations:

- ***PDUS (Primary Data User Station)*** - Main features:
  - frequency: 1694.5 MHz; bandwidth: 1.5 MHz; polarisation: linear
  - antenna diameter ~ 3 m, G/T ~ 10.5 dB/K, data rate 166 kbps.
- ***SDUS (Secondary Data User Station)*** - Main features:
  - frequency: 1691 (dedicated) and 1694.5 MHz (shared); bandwidth: 1.5 MHz; polarisation: linear
  - antenna diameter ~ 1.5 m, G/T ~ 2.5 dB/K, base band 1.6 kHz (analogue).

The satellites of the operational series (Meteosat 4 to 7) also provide:

- ***Meteorological Data Distribution (MDD) Service*** to relay meteorological maps (gridded or fac-simile) and other data from national meteorological centres to remote user terminals - Main features:
  - uplink: from up to four centres (currently from three: Rome, Bracknell and Toulouse);
  - user terminals: frequency 1695.68-1695.80 MHz (four 20-kHz-width channels spaced 31.2 kHz), antenna diameter ~ 2.4 m, G/T ~ 6.0 dB/K, data rate 2.4 kbps, linear polarisation.

Meteosat-8

Launched in August 2002, Meteosat-8, previously known as MSG-1, i.e. first flight model of the ***Meteosat Second Generation*** has completed its commissioning phase in December 2003. The position is 10.5°W. The satellite will be moved during January 2004 to a 3.4°W position to become operational in parallel with Meteosat-7.

Payload of Meteosat Second Generation

- ***SEVIRI (Spinning Enhanced VIS and IR Imager)***, a 12-channel VIS/IR radiometer with 3 km resolution in 11 VIS/IR narrow-bandwidth channels and 1 km in one broad-bandwidth VIS channel, 15 min image cycle. See the instrument sheet in Appendix.
- ***GERB (Geostationary Earth Radiation Budget experiment)***, 2-channel broad-band radiometer for Earth Radiation Budget, 42 km resolution, image cycle 5 min (or 15 min after integration to meet SNR requirements). See the instrument sheet in Appendix.
- ***Data Collection Service (DCS)*** to relay *in situ* observations from Data Collection Platforms (DCP) - Main features:
  - uplink: frequency 402.0-402.1 MHz for 33 international channels with 3 kHz bandwidth, 402.10-402.44 for 223 regional channels with 1.5 kHz bandwidth, 401.7-402.0 for 210 channels with 1.5 kHz bandwidth as contingency; data rate 100 kbps, polarisation right-hand circular.
- ***GEOSAR (Geostationary Search And Rescue)***, to relay distress signals from beacons at 406 MHz to a central European station of the international Search & Rescue system.

Data transmission from Meteosat Second Generation

Image data are transmitted in real time to the:

- Primary Ground Station (PGS). Main transmission characteristics:
  - frequency 1686.833 MHz, bandwidth ...... MHz, linear polarisation, data rate 3.2 Mbps.

After pre-processing, data are re-transmitted to user stations in S-band. There are two transmission services, both digital:

- ***HRIT, High Rate Information Transmission***
- ***LRIT, Low Rate Information Transmission***

Correspondingly, there are two types of user stations:

- ***HRUS (High Rate User Station)*** - Main features:
  - frequency: 1695.15 MHz; bandwidth: 1.96 MHz; polarisation: linear
  - antenna diameter ~ 3 m, G/T ~ 14 dB/K, data rate 1.0 Mbps;
- ***LRUS (Low Rate User Station)*** - Main features:
  - frequency: 1691.0 MHz; bandwidth: 0.66 MHz; polarisation: linear
  - antenna diameter ~ 2 m, G/T ~ 6 dB/K, data rate 128 kbps.

In addition, continuation is provided to:

- ***Meteorological Data Distribution (MDD) Service*** to relay meteorological maps and other data from national meteorological centres to remote user terminals - Main features:
  - uplink: from up to four centres (currently from three: Rome, Bracknell and Toulouse);
  - user terminals: not required in so far as the data are made available to HRUS and LRUS.

The EUMETCast service

As a matter of fact, the Meteosat-8 High Power Amplifier basic for the HRIT and LRIT services failed in orbit. Therefore the data to be disseminated (both images and DCP/MDD data) are currently transmitted by means of commercial satellites using the Digital Video Broadcast (DVB) system. This is called ***EUMETCast service***. There are two types of user terminals:

- Ku-band terminals (11.096 GHz) served by the HotBird satellites managed by EUTELSAT, optimally covering Europe; antenna diameter 85-180 cm; polarisation linear; rate 27.5 M symbols/s;
- C-band terminals (3.727 GHz) served by the Atlantic Bird satellites managed by EUTELSAT, covering also Africa, Eastern North/Central America and Western Asia; antenna diameter 2.4-3.7 m; polarisation left-hand circular; rate 5.96 M symbols/s.

Plans for Meteosat Third Generation

Planning for MTG (Meteosat Third Generation) has started in early 2001 and, at end-2003, initial requirements have been agreed and preliminary industrial studies are under way. The prototype MTG should be ready for launch in 2015. The following missions/instruments are being defined.

- ***MTG imager(s)*** - One or two instruments would address the following requirements:
  - High Resolution Fast Imagery, driven by nowcasting applications, with about 5 VIS/IR channels, resolution 0.5-1.0 km, cycle 2-5 min over a limited area (1/3 of the visible disk);
  - Full Disk High Spectral Imagery, evolution of MSG/SEVIRI, with about 15 VIS/IR channels, resolution 1.0-3.0 km, cycle 5-15 min; optional features such as a spectrometer in the 4.3-5.5 μm band (to be considered if there isn't an independent sounder) and sets of channels in the 14 μm band and around 0.76 μm (for cloud top height) also are being studied.
- ***MTG sounder*** - An IR spectrometer is foreseen, to provide high vertical resolution. Main features:
  - range 4.0 to ≥ 14.3 μm, resolution 0.5 cm^{-1} (goal at 14 μm) to 1.25 cm^{-1} (threshold at 5 μm)
  - geometric resolution: from 3 to 6 km (at 5 μm) and 6 to 12 km (at 14 μm)
  - cycle: 15 to 60 min for full disk, correspondingly less for limited areas.
- ***MTG lightning mapper*** - CCD camera operating at 777.4 nm (O_2), resolution 5-10 km, time resolution ~ 1 ms, probability of lightning detection > 90 %, probability of false detection < 1 s^{-1}.
- ***Follow-on of GERB***: to be considered at a later stage.
- ***Chemistry mission by UV/VIS spectroscopy***: requirements being developed.
- ***Precipitation mission by MW/Sub-mm imagery/sounding***: being considered as a side activity.

Instrument sheets of the MTG imager(s), sounder and lightning mapper are provided in Appendix.

1.3 The GOES programme

The GOES programme is designed to cover two positions (GOES-W at 135°W, GOES-E at 75°W) by two satellites, with one common backup satellite in intermediate position (105°W) to be moved in replacement of any of the two in case of failure. The programme evolved through the following phases:

- the precursor ***ATS (Application Technology Satellite)***, ATS-1 and ATS-3 spin-stabilised, ATS-6 three-axis stabilised;
- the prototype ***SMS (Synchronous Meteorological Satellite)*** (SMS-1 and SMS-2) and the first three ***GOES (Geostationary Operational Environmental Satellite)*** (GOES-1/2/3), spin-stabilised, equipped with an imager (VISSR);
- GOES 4 to 7, with VISSR upgraded to VAS to provide either imagery or sounding;
- GOES-8 and follow-on (to continue to GOES-16), three-axis stabilised, equipped with independent IMAGER and SOUNDER.

Table 2.3.1 records the chronology of the GOES programme.

Table 2.3.1 - Chronology of the GOES programme *(in bolt the satellites active at end 2003)*

Satellite	Launch	End of service	Position	Status (Dec 2003)	Instruments
ATS-1	6 Dec 1966	1 Dec 1978		Inactive	SSCC
ATS-3	6 Nov 1967	1 Dec 1978		Inactive	MSSCC
ATS-6	30 Apr 1974	3 Aug 1979		Inactive	VHRR
SMS-1	17 May 1974	21 Jan 1981		Inactive	VISSR, DCIS, SEM
SMS-2	6 Feb 1975	5 Aug 1982		Inactive	VISSR, DCIS, SEM
GOES-1	16 Oct 1975	7 Mar 1985		Inactive	VISSR, DCIS, SEM
GOES-2	16 Jun 1977	during 1993		Inactive	VISSR, DCIS, SEM
GOES-3	16 Jun 1978	during 1993		Inactive	VISSR, DCIS, SEM
GOES-4	9 Sep 1980	11 Nov 1988		Inactive	VAS, DCIS, SEM
GOES-5	22 May 1981	18 Jul 1990		Inactive	VAS, DCIS, SEM
GOES-6	28 Apr 1983	during 1989		Inactive	VAS, DCIS, SEM
GOES-7	26 Feb 1987	11 Jan 1996		Inactive	VAS, DCIS, SEM
GOES-8	**13 Apr 1994**	**expected ≥ 2004**	**165°E**	**Backup** (partly)	**IMAGER, SOUNDER, DCIS, SEM, GEOSAR**
GOES-9	**23 May 1995**	**expected ≥ 2004**	**155°E**	**Operational** (partly)	**IMAGER, SOUNDER, DCIS, SEM, GEOSAR**
GOES-10	**25 Apr 1997**	**expected ≥ 2005**	**135°W**	**Operational**	**IMAGER, SOUNDER, DCIS, SEM, GEOSAR**
GOES-11	**3 May 2000**	**expected ≥ 2007**	**105°W**	**Standby**	**IMAGER, SOUNDER, DCIS, SEM, GEOSAR**
GOES-12	**23 Jul 2001**	**expected ≥ 2008**	**75°W**	**Operational**	**IMAGER, SOUNDER, DCIS, SEM, SXI, GEOSAR**
GOES-13	Jul 2004	expected ≥ 2011		Ready	IMAGER, SOUNDER, DCIS, SEM, SXI, GEOSAR
GOES-14	Apr 2007	expected ≥ 2014		Being built	IMAGER, SOUNDER, DCIS, SEM, SXI, GEOSAR
GOES-15	Oct 2008	expected ≥ 2015		Planned	IMAGER, SOUNDER, DCIS, SEM, SXI, GEOSAR
GOES-R	Apr 2012	expected ≥ 2019		Being defined	ABI, HES + TBD

Short information on past series

ATS-1 and ATS-2 were equipped, respectively, with SSCC (Spin Scan Cloud Camera) e MSSCC (Multi-color SSCC). ATS-6 was equipped with VHRR (Very High Resolution Radiometer) that, afterwards, became operational on the INSAT satellites.

The SMS-1, SMS-2 and GOES 1 to 3 were equipped with:

- ***VISSR (Visible and Infrared Spin Scan Radiometer)***, a 2-channel VIS/IR radiometer with resolution 0.9 km in VIS (0.55-0.75 μm) and 7 km in IR (10.5-12.6 μm); cycle 30 min.

On GOES 4 to 7 VISSR was upgraded to enable temperature/humidity sounding, alternate with images:

- ***VAS (VISSR Atmospheric Sounder)***, adding to the two VISSR channels further 12 narrow-bandwidth channels centred at 3.94, 4.44, 4.51, 6.7, 7.2, 11.2, 12.7, 13.3, 14.0, 14.2, 14.5 and 14.7 µm; resolution 7 or 14 km depending on the channel, cycle lasting as necessary to collect enough energy as required for profile retrieval; generally used for limited area scanning.

Fig. 2.3.1 and ***Fig. 2.3.2*** show the change of structure from the GOES 4/5/6/7 spacecrafts to the current series (GOES-8 and follow-on).

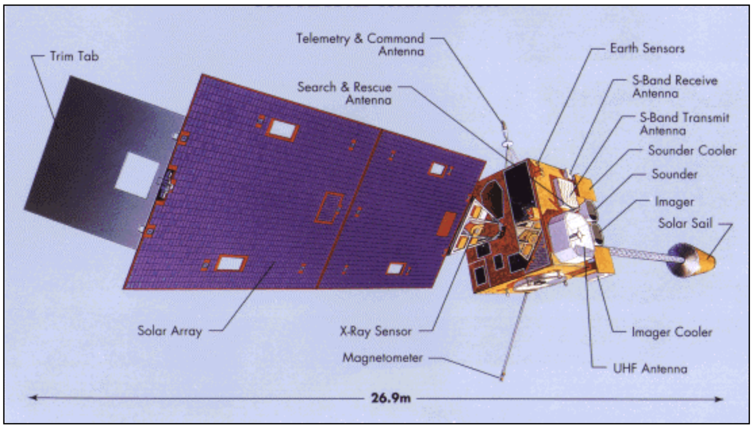


Fig. 2.3.1 - View of GOES-4/5/6/7.

Fig. 2.3.2 – Sketch view of GOES-8 and follow-on.

GOES-8

Launched in April 1994, GOES-8 was the first of the 3-axis stabilised series. It has served as GOES-E at 75°W until spring 2003, when it was replaced by GOES-12. Then it has been moved to 165°E to serve as backup to GOES-9. It has several operational limitations.

GOES-9

Launched in May 1995, GOES-9 has served as GOES-W at 135°W until 1999, when the accumulation of a number of malfunctions led to transfer operations to GOES-10 and place GOES-9 in a standby position at 106°W. In early 2003 it has been moved to 155°E to partially fill the gap due to the end-of-life of GMS-5, waiting for the launch of MTSAT.

GOES-10 *(current GOES-W)*

Launched in April 1997, GOES-10 was originally placed in the standby position at 105°W. Thereafter, in 1999, it has replaced GOES-9 as the operational satellite at 135°W.

GOES-11 *(current common backup of GOES-E and GOES-W)*

Launched in May 2000, GOES-11 is the current standby satellite at 105°W between GOES 10 and 12.

GOES-12 *(current GOES-E)*

Launched in July 2001, GOES-12 was originally placed in the standby position at 105°W. Thereafter, spring 2003, it has replaced GOES-8 as the operational satellite at 75°W.

Payload of GOES 8 to 15

- ***IMAGER***, a 5-channel VIS/IR radiometer with 4.0 km resolution in four IR channels and 1.0 km in the VIS channel, 30 min image cycle (less for limited areas). See the instrument sheet in Appendix.
- ***SOUNDER***, a 19-channel IR sounding radiometer (including one in VIS) with 8.0 km resolution, generally used for limited areas (e.g., 1000 x 1000 km^2 in 5 min, 3000 x 3000 km^2 in 42 min: it would be 8 h for full disk). See the instrument sheet in Appendix.
- ***Data Collection and Interrogation Service (DCIS)*** to relay *in situ* observations from Data Collection Platforms (DCP) either transmitting at fixed times or after interrogation. This mission is in use, with progressive updating, since SMS-1. Main features:
  - uplink: two bands, frequencies 401.900 MHz and 402.200 MHz, bandwidth 350 kHz each for a total of 223 channels of bandwidth 3 kHz; data rate 100 kbps, polarisation right-hand circular;
  - downlink for interrogation: two frequencies, 468.8250 MHz and 468.8375 MHz, bandwidths 200 kHz each, data rate 100 kbps, polarisation right-hand circular.
- ***Space Environment Monitoring (SEM)***, in use, with progressive updating, since SMS-1. A set of instruments for *in situ* measurement, at the platform's altitude, of:
  - EPS (Energetic Particles Sensor) for low-energy electron, proton and alpha particles
  - HEPAD (High Energy Proton and Alpha Particles Detector)
  - XRS (X-Ray Sensor)
  - two redundant Magnetometers.
- ***Solar X-ray Imager (SXI)***, starting with GOES-12, to image the sun each minute.
- ***PDR, Processed Data Relay***, associated to the WEFAX service (in use since SMS-1).
- ***GEOSAR (Geostationary Search And Rescue)***, to relay distress signals from beacons at 406 MHz to the American Search & Rescue Coordination Center.

Data transmission from GOES

GOES data are transmitted in real time to the:

- Command and Data Acquisition station (CDA). Main transmission characteristics:
  - frequency 1676.2 MHz, bandwidth 6.0 MHz, linear polarisation, data rate 3.0 Mbps.

Afterwards, data are re-transmitted to several centres in several modes. The ones that concern most users occurs after pre-processing, to two types of S-band stations:

- ***GVAR (GOES Variable Data Format)***, for processed image and sounding data - Main features:
  - frequency: 1685.7 MHz; bandwidth: 5.0 MHz; polarisation: linear
  - antenna diameter ~ 3 m, G/T ~ 16 dB/K, data rate 2.1 Mbps;
- ***WEFAX***, for selected image frames - Main features:
  - frequency: 1691.0 MHz; bandwidth: 1.0 MHz; polarisation: linear
  - antenna diameter ~ 1.5 m, G/T ~ 2.5 dB/K, base band 1.6 kHz (analogue).

The WEFAX mode is fully consistent with that one of Meteosat 1 to 7. GOES-12 has started to alternate the analogue WEFAX transmission to the digital mode as MSG (LRIT), i.e. for stations:

- ***LRUS (Low Rate User Station)*** - Main features:
  - frequency: 1691.0 MHz; bandwidth: 0.66 MHz; polarisation: linear
  - antenna diameter ~ 2 m, G/T ~ 6 dB/K, data rate 128 kbps.

It is foreseen that, during 2005, WEFAX will definitively be replaced by LRIT.

Plans for GOES next generation starting with GOES-R (GOES-16)

Planning for GOES-R has started in early 2001 and is making progress under the guidance of the yearly GOES User Conference. The launch should be in 2012. The following instruments are being defined.

- ***ABI (Advanced Baseline Imager)***, with about 16 VIS/IR channels, resolution 2 km for 12 channels, 0.5 km for one VIS channel, 1.0 km for other three SW channels, cycle 15 min for full disk, 5 min for 3000 x 5000 km^2 ("CONUS", Continental United States), 30 s for 1000 x 1000 km^2;
- ***HES (Hyperspectral Environmental Suite)***, currently defined to address several objectives: full disk sounding, limited-area nowcasting and coastal water observation (ocean colour). Spectral range for sounding from 4.44 µm (option 3.68 µm) to 15.38 µm (with gaps) with resolving power changing with band from 1000 to 3000, plus one VIS channel; for coastal waters about 14 VIS/NIR channel of 20 nm width and possibly 3 SWIR channels of 30 or 50 nm width and the split IR window at 11 and 12 µm. Geometric resolution: 2 to 10 km for sounding (0.5-1.0 km for the VIS channel), 0.15 to 2 km for coastal waters. Cycle: maximum 1 h for full disk, down to minutes depending on operating mode. It is realised that HES could be a suite of distinct instruments.
- ***LMS (Lighting Mapper Sensor)*** CCD camera operating at 777.4 nm (O_2), resolution 8 km, time resolution 2 ms, probability of lightning detection > 90 %, probability of false detection < 1 s^{-1}.
- ***MW/Sub-mm imaging/sounder for precipitation***.

Instrument sheets of ABI, HES and LMS are provided in Appendix.

1.4 The GMS and MTSAT programmes

The Japanese ***GMS (Geosynchronous Meteorological Satellite)*** [1] was a spin-stabilised satellite (***Fig. 2.4.1***) to cover the position 140°E. Its successor, ***MTSAT (Multi-functional Transport Satellite)***, is 3-axis stabilised (***Fig. 2.4.2***), coupling the meteorological mission to an aviation navigation one. ***Table 2.4.1*** records the chronology of the GMS/MTSAT programme

Tabella 2.4.1 - Chronology of the GMS/MTSAT programme *(no satellite active at end 2003)*

Satellite	Launch	End of service	Position	Status (Dec 2003)	Instruments
GMS-1	14 Jul 1977	?		Inactive	VISSR, SEM, DCS
GMS-2	11 Aug 1981	?		Inactive	VISSR, SEM, DCS
GMS-3	3 Aug 1984	during 1994		Inactive	VISSR, SEM, DCS
GMS-4	6 Sep 1989	24 Feb 2000		Inactive	VISSR, SEM, DCS
GMS-5	18 Mar 1995	during 2003		Inactive	VISSR, SEM, DCS
MTSAT-1	2004	expected ≥ 2012	140°E	Close to launch	JAMI, DCS
MTSAT-2	2005	expected ≥ 2014		Being built	JAMI, DCS

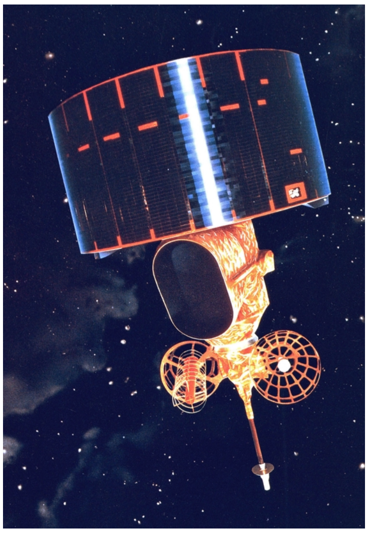


Fig. 2.4.1 – View of GMS.

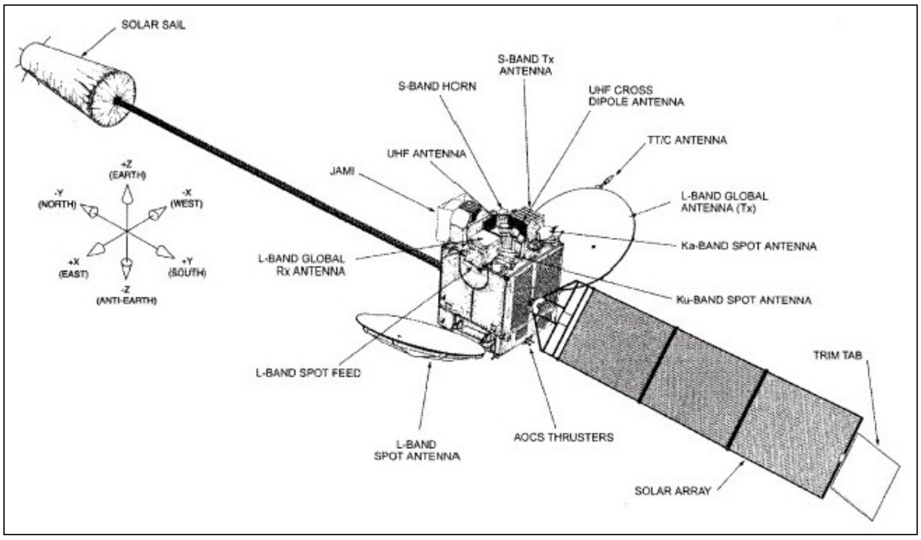


Fig. 2.4.2 – Sketch view of MTSAT.

The last GMS satellite in the series, GMS-5, is now being supplemented by GOES-9 at 155°E. It was equipped with:

- ***VISSR (Visible and Infrared Spin-Scan Radiometer)***, a 4-channel VIR/IR radiometer with 5.0 km resolution in three IR channels (6.5-7.0 µm, 10.5-11.5 µm and 11.5-12.5 µm) and 1.25 km in the VIS channel (0.55-0.90 µm), 30 min image cycle (less for limited areas).
- ***SEM (Space Environment Monitor)***
- ***DCS (Data Collection Service)***, also foreseen on MTSAT (see next).

The first launch of MTSAT failed in 1999. ***MTSAT-1*** (currently called MTSAT-1R) will be launched in early 2004, followed by ***MTSAT-2*** one year later (to be placed in standby until 2009).

[1] Original name: ***Himawari***, that means “Sun Flower”.

Payload of MTSAT

- ***JAMI (Japanese Advanced Meteorological Imager)***, similar to the GOES IMAGER: a 5-channel VIS/IR radiometer with 4.0 km resolution in four IR channels and 1.0 km in the VIS channel, 60 min image cycle (less for limited areas). See the instrument sheet in Appendix.
- ***Data Collection Service (DCS)*** to relay *in situ* observations from Data Collection Platforms (DCP) either transmitting at fixed times or after interrogation - Main features:
  - uplink: two bands, frequencies 402.0-402.1 MHz for international DCPs (33 channels of bandwidth 3 kHz), 402.1-402.4 MHz for regional DCPs (100 channels of bandwidth 3 kHz); data rate 100 kbps, polarisation right-hand circular;
  - downlink for interrogation: frequency .... MHz, bandwidth ...... kHz each, data rate 100 kbps, polarisation right-hand circular.

Data transmission from MTSAT

MTSAT data are transmitted in real time to the:

- Command and Data Acquisition Station (CDAS). Main transmission characteristics:
  - frequency .... MHz, bandwidth .... MHz, linear polarisation, data rate ..... Mbps.

Afterwards, data are re-transmitted to user stations. Initially, MTSAT will provide compatibility with existing receiving stations for GMS; then, in the course of 2005 there will be an upgrading.

- ***HiRID (High Resolution Imager Data)*** provides service continuity for the Medium-scale Data Utilisation Stations (MDUS). Main features:
  - frequency: 1687.1 MHz; bandwidth: 2.0 MHz; polarisation: linear
  - antenna diameter ~ 4 m, G/T ~ 10.4 dB/K, data rate 660 kbps;
- ***HRIT (High Resolution Information Transmission)*** will replace HiRID in 2005. Main features:
  - frequency: 1687.1 MHz; bandwidth: 5.2 MHz; polarisation: linear
  - antenna diameter ~ 4 m, G/T ~ 10.4 dB/K, data rate 3.5 Mbps;
- ***WEFAX*** will be initially time-shared with and then replaced by the ***LRIT (Low Rate Information Transmission)***, that also similar to MSG and GOES. Main features:
  - frequency: 1691.0 MHz; bandwidth: 250 kHz; polarisation: linear
  - antenna diameter ~ 2.5 m, G/T ~ 3 dB/K, data rate 75 kbps.

1.5 The GOMS programme

The Russian ***GOMS (Geostationary Operational Meteorological Satellite)*** [2] is a 3-axis stabilized satellites (***Fig. 2.5.1***) due to cover the 76°E position. The first spacecraft was launched in 1994, but its functioning experienced several problem till final deactivation in 2000. A second flight unit is now being prepared. ***Table 2.5.1*** records the chronology of the GOMS programme.

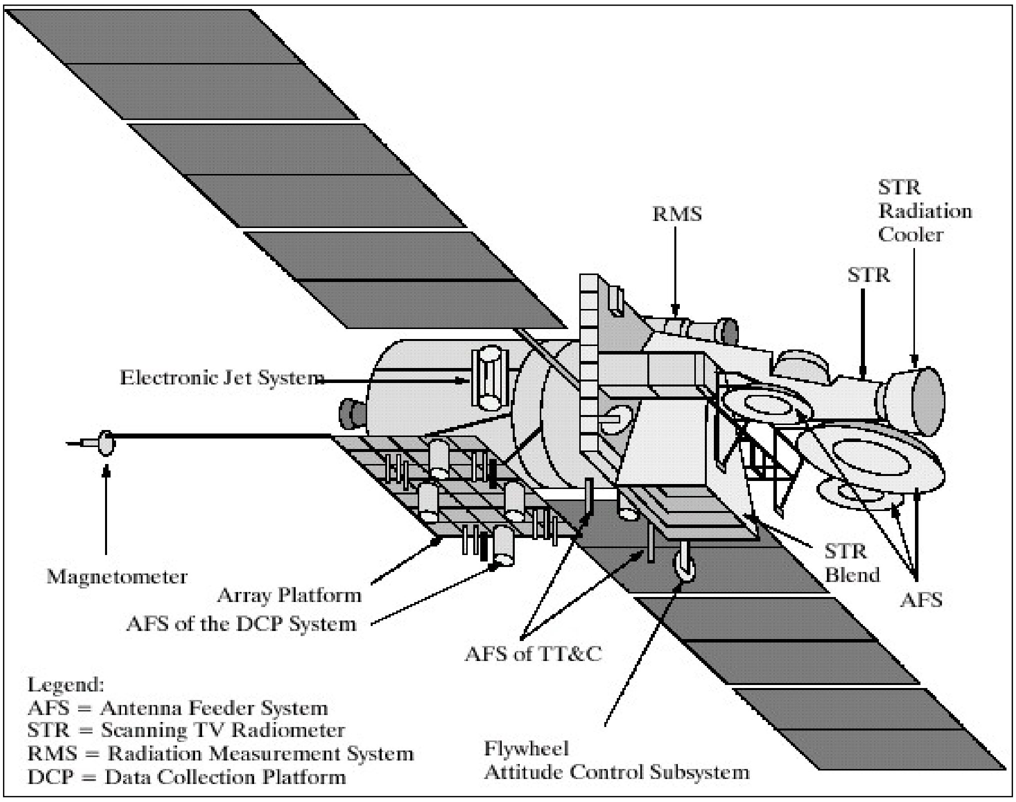


Fig. 2.5.1 – Sketch view of GOMS-N1.

Table 2.5.1 - Chronology of the GOMS programme *(no satellite active at end 2003)*

Satellite	Launch	End of service	Position	Status (Dec 2003)	Instruments
GOMS-N1	31 Oct 1994	during 2000		Inactive	STR, DCS, RMS, GEOSAR
GOMS-N2	2006	expected ≥ 2015	76°E	Being built	MSU-G, DCS, RMS, GEOSAR

GOMS-N1 was equipped with the radiometer:

- ***STR (Scanning TV Radiometer)*** was a 3-channels VIS/IR radiometer; 6.5 km resolution in two IR channels (6.0-7.0 μm and 10.5-12.5 μm), 1.25 km in VIS (0.46-0.70 μm), 30 min image cycle.

GOMS-N2 is being built for launch in 2006. Its imaging radiometer is being developed attempting to match the performance of the MSG SEVIRI.

[2] Original name: ***Elektro***.

Payload of GOMS-N2

- ***MSU-G***, a 12-channel VIS/IR radiometer with 4.0 km resolution in eight IR channels and 1.0 km in four VIS/NIR channels, 30 min image cycle (less for limited areas). See the instrument sheet in Appendix.
- ***Data Collection and Interrogation Service (DCS)*** (also on GOMS-N1), to relay *in situ* observations from Data Collection Platforms (DCP) either transmitting at fixed times or after interrogation - Main features:
  - uplink: two bands, frequencies 402.0-402.1 MHz for international DCPs (33 channels of bandwidth 3 kHz), 402.1-402........ MHz for regional DCPs (300 channels of bandwidth .... kHz); data rate 100 kbps, polarisation right-hand circular;
  - downlink for interrogation: 469.0 MHz, bandwidths ...... kHz, data rate 100 kbps, polarisation right-hand circular.
- ***Radiation Measurement System (RMS***) (also on GOMS-N1), for *in situ* measurement of charged particles of the solar wind at the platform's altitude.
- ***GEOSAR (Geostationary Search And Rescue)***, to relay distress signals from beacons at 406 MHz to stations of the international Search & Rescue system.

Data transmission from GOMS-N2

GOMS-N2 data are transmitted in real time to the:

- Command and Data Acquisition station (CDA). Main transmission characteristics:
  - frequency .... MHz, bandwidth .... MHz, linear polarisation, data rate ..... Mbps.

Afterwards, data are re-transmitted to user stations. The broadcast will comply with the HRIT and LRIT standards and initially, with WEFAX for continuity reasons:

- ***HRIT (High Resolution Information Transmission)***. Main features:
  - frequency: 1685.0 MHz; bandwidth: .... MHz; polarisation: linear
  - antenna diameter ~ ...... m, G/T ~ .... dB/K, data rate .... Mbps;
- ***WEFAX*** will be initially time-shared with and then replaced by the ***LRIT (Low Rate Information Transmission)***, that also similar to MSG, GOES and MTSAT. Main features of LRIT:
  - frequency: 1691.0 MHz; bandwidth: .... kHz; polarisation: linear
  - antenna diameter ~ .... m, G/T ~ .... dB/K, data rate .... kbps.

1.6 The FY-2 programme

The Chinese *FY-2 (Feng-Yun-2)* [3] is spin stabilised (*Fig. 2.6.1*), due to cover the 105°E position. ***Table 2.6.1*** records the chronology of the FY-2 programme.

Table 2.6.1 - Chronology of the FY-2 programme *(in bolt the satellites active at end 2003)*

Satellite	Launch	End of service	Position	Status (Dec 2003)	Instruments
FY-2A	**10 Jun 1997**	**expected ≥ 2004**	**86.5°E**	**Backup (partly)**	**S-VISSR, DCS, SEN**
FY-2B	**26 Jun 2000**	**expected ≥ 2006**	**105°E**	**Operational**	**S-VISSR, DCS, SEM**
FY-2C	2004	expected ≥ 2009		Close to launch	S-VISSR (improved), DCS, SEM
FY-2D	2006	expected ≥ 2011		Being built	S-VISSR (improved), DCS, SEM
FY-2E	2009	expected ≥ 2014		Planned	S-VISSR (improved), DCS, SEM

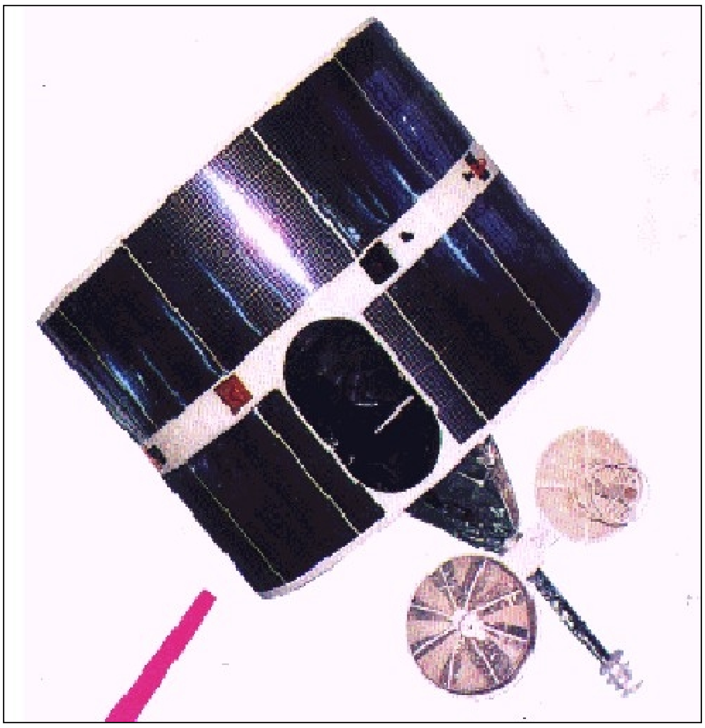


Fig. 2.6.1 – View of FY-2.

FY-2A

Launched in June 1997 on the 105°E position, was moved to 86.5°E in July 2000 to leave the operational service to FY-2B. It still has some capabilities that are used from time to time to backup FY-2B at occasions.

FY-2B

Launched in June 2000, it is the current operational satellite at 105°E.

FY-2C, 2D and 2E

FY-2C will be launched in 2004, and followed by FY-2D (2006) and FY-2E (2009). The payload will be improved in respect of that one of FY-2A and FY-2B.

[3] ***Feng-Yun*** means "Wind and Cloud". The "2" series is geostationary, the "1" and "3" series sunsynchronous.

Payload of FY-2

- ***S-VISSR (Stretched Visible and Infrared Spin Scan Radiometer)*** – The version of FY-2A/B has three VIS/IR channels (0.5-1.05 µm, 6.3-7.6 µm and 10.5-12.5 µm) the improved version for FY-2 C/D/E splits the IR channel in two and adds a 3.5-4.0 µm channel. The resolution also is slightly improved: from 5.76 km (IR) and 1.44 km (VIS), to 5.0 km (IR) and 1.25 km (VIS). The image cycle is 30 min. See the instrument sheet in Appendix.
- ***Data Collection Service (DCS)*** - Main features:
  - uplink: two bands, frequencies 402.0-402.1 MHz for international DCPs (33 channels of bandwidth 3 kHz), 401.1-401.4 MHz for regional DCPs (100 channels of bandwidth 3 kHz); data rate 100 kbps, polarisation right-hand circular.
- ***SEM (Space Environment Monitor)***.

Data transmission from FY-2

FY-2 data are transmitted in real time to the:

- Command and Data Acquisition Station (CDAS). Main transmission characteristics:
  - frequency .... MHz, bandwidth .... MHz, linear polarisation, data rate ..... Mbps.

Afterwards, data are re-transmitted to user stations. The broadcast will comply with the HRIT and LRIT standards and initially, with WEFAX for continuity reasons:

- ***S-VISSR Data Transmission***, compatible with MDUS acquisition stations. Main features:
  - frequency: 1687.5 MHz; bandwidth: 2.0 MHz; polarisation: linear
  - antenna diameter ~ ...... m, G/T ~ .... dB/K, data rate 660 kbps.
- ***WEFAX*** from FY-2 A/B, ***LRIT (Low Rate Information Transmission)*** from FY-2 C/D/E, similar to MSG, GOES, MTSAT and GOMS-N2. Main features of LRIT:
  - frequency: 1691.0 MHz; bandwidth: 260 kHz; polarisation: linear
  - antenna diameter ~ .... m, G/T ~ .... dB/K, data rate .... kbps.

1.7 The INSAT and Kalpana programmes

Although not part of the GOS, the ***Indian National Satellite programme (INSAT)*** supports national requirements and is coordinated within CGMS. It combines the meteorological mission with the function of supporting domestic telecommunications. It is a 3-axis stabilised satellite (***Fig. 2.7.1***), with generally two flight models in orbit, at 74°E and 83°E. Not all INSAT flight models carry a meteorological payload. In 2002 a small satellite entirely dedicated to meteorology, originally named ***MetSat***, thereafter renamed ***Kalpana-1*** [4] was launched over 74°E. ***Table 2.7.1*** records the chronology of the INSAT and Kalpana programmes.

Table 2.7.1 - Chronology of the INSAT and Kalpana programmes *(in bolt the satellites active at end 2003)*

Satellite	Launch	End of service	Position	Status (Dec 2003)	Instruments
INSAT-1A	10 Apr 1982	6 Sep 1982		Inactive	VHRR, DCS
INSAT-1B	30 Aug 1983	Jul 1993		Inactive	VHRR, DCS
INSAT-1C	22 Jul 1988	during 1989		Inactive	VHRR, DCS
INSAT-1D	12 Jun 1990	May 2002		Inactive	VHRR, DCS
INSAT-2A	9 Jul 1992	?		Inactive	VHRR, DCS
INSAT-2B	**22 Jul 1993**	**expected ≥ 2004**	**111.5°E**	**Backup (partly)**	**VHRR, DCS**
INSAT-2C	6 Dec 1995	?		Inactive	No meteo
INSAT-2D	3 Jun 1997	4 Oct 1997		Inactive	VHRR, DCS
INSAT-2E	**3 Apr 1999**	**expected ≥ 2004**	**83°E**	**Operational**	**VHRR, CCD, DCS**
INSAT-3A	**10 Apr 2003**	**expected ≥ 2008**	**93.5°E**	**Operational**	**VHRR, CCD, DCS**
INSAT-3B	22 mar 2000	expected ≥ 2005		Operational	No meteo
INSAT-3C	24 gen 2002	expected ≥ 2007		Operational	No meteo
INSAT-3D	2006	expected ≥ 2010		Being built	IMAGER, SOUNDER, DCS
Kalpana-1	**12 set 2002**	**expected ≥ 2007**	**74°E**	**Operational**	**VHRR, DCS**
Kalpana-2	2005	expected ≥ 2010		Being built	VHRR, DCS

The series INSAT-1, used from 1982 to 2002, was carrying an imager, ***VHRR***, derived by ATS-6 (see Table 2.3.1). It only had two VIS/IR channels (0.55-0.75 µm and 10.5-12.5 µm); resolution 11 km in IR, 2.75 km in VIS.

INSAT-2B/E and ***3A***

INSAT 2E, launched in April 1999, is the currently operational satellite over 83°E, supported by ***INSAT-2B*** with limited capabilities. ***INSAT-3A*** also is operational, on 93.5°E.

KALPANA-1/2

The Kalpana-1 satellite was launched in September 2002 as a dedicated meteorological mission. It provides the operational service on 74°E. A second flight model is being built for launch in 2005.

Payload of INSAT and Kalpana satellites

- ***VHRR (Very High Resolution Radiometer)*** is a 3-channels VIS/IR radiometer with 8 km resolution in the two IR channels and 2 km in the VIS channel (only two channels on INSAT-1 and INSAT-2 A/B). The image cycle is three hours, but more frequent images are taken at intervals to generate trace-motion winds. See the instrument sheet in Appendix.
- on INSAT-2E and 3/A: ***CCD Camera***, a TV camera with three VIS/NIR channels at 1 km resolution, image cycle 3 hours, more frequent on demand. See the instrument sheet in Appendix.
- ***Data Collection Service (DCS)*** - Main features:
  - uplink: frequencies 402.65-402.85 MHz for international DCPs (....... channels of bandwidth .... kHz), data rate 4.8 kbps, polarisation right-hand circular.

[4] Kalpana is the name of the female astronaut of Indian ancestery lost with the accident of the Shuttle “Columbia” in February 2003.

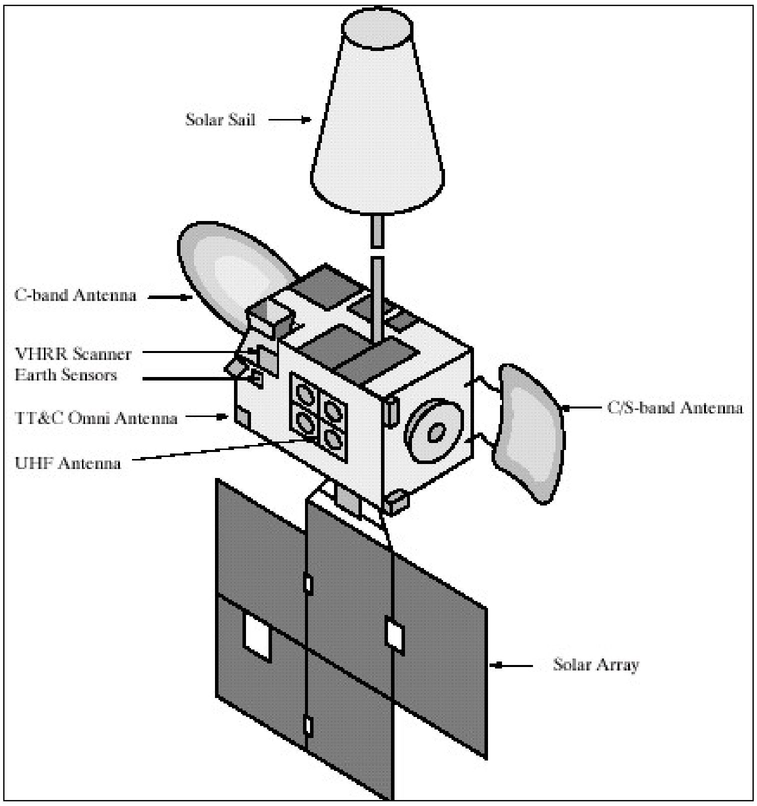


Fig. 2.7.1 – Sketch view of INSAT satellites

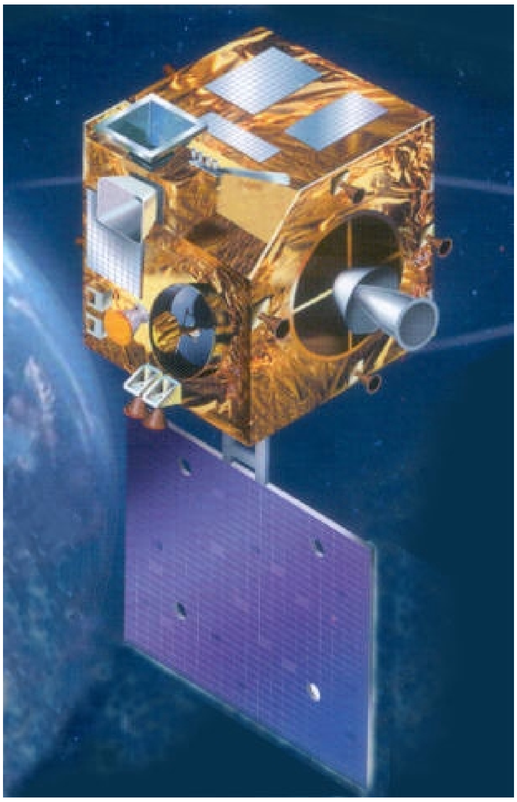


Fig. 2.7.2 – View of Kalpana.

INSAT-3D

The traditional difficulty with INSAT usage was the need to share satellite resources with the (priority) telecommunication mission. ***INSAT-3D***, instead, is being designed to be dedicated to meteorology. It will have imagery and sounding capabilities similar to those of the current GOES series:

- ***IMAGER***, a 6-channels VIS/IR radiometer with 4.0 km resolution in 3 IR channels, 1.0 km in the VIS channel, 8 km in the water-vapour channels. Image cycle .... min. See the instrument sheet in Appendix.
- ***SOUNDER***, a 19-channel IR radiometer (including a VIS channels), 10 km resolution, Cycle .... hours See the instrument sheet in Appendix.

Data transmission from INSAT and Kalpana

INSAT and Kalpana data are first transmitted in real time to:

- Command and Data Acquisition Station (CDAS): main transmission characteristics:
  - frequency .... MHz, bandwidth ..... MHz, linear polarisation, data rate ...... Mbps).

After ground processing, data are provided to the users by:

- ***Meteorological Data Distribution (MDD) Service***. Regular transmissions occur at 3-hour interval, with increased frequency during the cyclone season. Main features:
  - uplink: from the system central processing facility;
  - user terminals: frequency 2599.225 MHz, bandwidth .... KHz, linear polarisation, antenna diameter ~ .... m, G/T ~ .... dB/K, base band 10 kHz (analogue)

  With INSAT-3D the system will probably be transformed in digital, possibly following the HRIT and LRIT standards.

1.8 Coverage provided by geostationary satellites at end-2003 and in year 2006

In this section the compliance of the constellation of geostationary satellites with WMO requirements is evaluated. Since the requirement calls for six satellites equally spaced around the equator, ***Table 2.8.1*** identifies six sectors each one 60° wide. However, since the current situation is rather unstable (several satellites are end-of-life), and waiting for GOMS-N2, MTSAT and INSAT-3D, it is useful to also consider the perspective situation in year 2006 according to known plans. This is shown in ***Table 2.8.2***.

Table 2.8.1 - Coverage from GEO as of end 2003 (CGMS XXXI)

Geographic area	Satellite	Position	Status (Dec 2003)	Main instruments
30°W - 30°E Europe, Africa, Eastern Atlantic	**Meteosat-8**	**3.4°W**	**Commissioned**	**SEVIRI, GERB**
	Meteosat-7	**0°**	**Operational**	**MVIRI**
	Meteosat-6	10°E	Backup + Rapid scan	MVIRI
30°E - 90°E Western Asia, Indian Ocean	**Meteosat-5**	**63°E**	**Operational**	**MVIRI**
	Kalpana-1	**74°E**	**Operational**	**VHRR**
	INSAT-2E	83°E	Operational (with limitations)	VHRR, CCD
	FY-2A	86.5°E	Partial backup	S-VISSR
90°E - 150°E East-Asia, Australia, West- Pacific	**INSAT-3A**	**93.5°E**	**Operational**	**VHRR, CCD**
	FY-2B	**105°E**	**Operational**	**S-VISSR**
150°E - 150°W Oceania, Central Pacific	**GOES-9**	**155°E**	**Operational** (with limitations)	**IMAGER, SOUNDER**
	GOES-8	165°E	Backup (partly)	IMAGER, SOUNDER
150°W - 90°W East-Pacific, North-West America	**GOES-10**	**135°W**	**Operational**	**IMAGER, SOUNDER**
	GOES-11	105°W	Standby	IMAGER, SOUNDER
90°W - 30°W South America, NE America, West Atlantic	**GOES-12**	**75°W**	**Operational**	**IMAGER, SOUNDER**

Table 2.8.2 - Coverage from GEO as expected for 2006 (CGMS XXXI)

Geographic area	Satellite	Position	Status (2006)	Main instruments
30°W - 30°E Europe, Africa, Eastern Atlantic	**Meteosat-9**	**0°**	**Operational**	**SEVIRI, GERB**
	Meteosat-8	~ 0°	Standby	SEVIRI, GERB
30°E - 90°E Western Asia, Indian Ocean	**Kalpana-2**	**74°E**	**Operational**	**VHRR**
	GOMS-N2	**76°E**	**Operational**	**MSU-G**
	INSAT-3D	**83°E**	**Operational**	**IMAGER, SOUNDER**
90°E - 150°E East-Asia, Australia, West- Pacific	INSAT-3A	93.5°E	Backup	VHRR, CCD
	FY-2C	**105°E**	**Operational**	**S-VISSR**
	MTSAT-1	**140°E**	**Operational**	**JAMI**
	MTSAT-2	~ 140°E	Standby	JAMI
150°E - 150°W Oceania, Central Pacific				
150°W - 90°W East-Pacific, North-West America	**GOES-11**	**135°W**	**Operational**	**IMAGER, SOUNDER**
	GOES-13	105°W	Standby	IMAGER, SOUNDER
90°W - 30°W South America, NE America, West Atlantic	**GOES-12**	**75°W**	**Operational**	**IMAGER, SOUNDER**

Table 2.8.3 shows the distribution of gaps of coverage in respect of the required ± 55° latitude. The only serious gap is over Oceania and Central Pacific in 2006.

Table 2.8.3 – Latitudinal coverage at end 2003 and expected for 2006 *(highlighted if < 55°)*

2003	GOES-10	GOES-12	Meteosat-8	Meteosat-7	Meteosat-5	Kalpana-1	INSAT-3A	FY-2B	GOES-9	GOES-10
S.S.P.	135°W	75°W	3.4°W	0°	63°E	74°E	93.5°E	105°E	155°E	135°W
Δ SSP	60°	71.6°	3.4°	63°	11°	19.5°	11.5°	50°	70°	
Latitude cover	± 55°	± 52°	± 60°	± 54°	± 60°	± 60°	± 60°	± 57°	± 52°	

2006	GOES-11	GOES-12	Meteosat-8	Kalpana-2	GOMS-N2	INSAT-3D	FY-2C	MTSAT-1	GOES-11
S.S.P.	135°W	75°W	0°	74°E	76°E	83°E	105°E	140°E	135°W
Δ SSP	60°	75°	74°	2°	7°	22°	35°	85°	
Latitude cover	± 55°	± 51°	± 51°	± 60°	± 60°	± 60°	± 59°	± 47°	

Fig. 2.8.1 and ***Fig. 2.8.2*** show the composite coverage from the operational satellites at end-2003 and in 2006, respectively (in bolt in Tables 2.8.1 and 2.8.2). The figures should be compared with the WMO requirement shown in Fig. 1.1. It can be noted that, from a "mechanical" viewpoint, i.e. independent on data quality (the subject of section 2.9, next), the coverage situation, though not optimal, is and will remain satisfactory. Also, there is enough built-in contingency to keep the system operational under most circumstances.

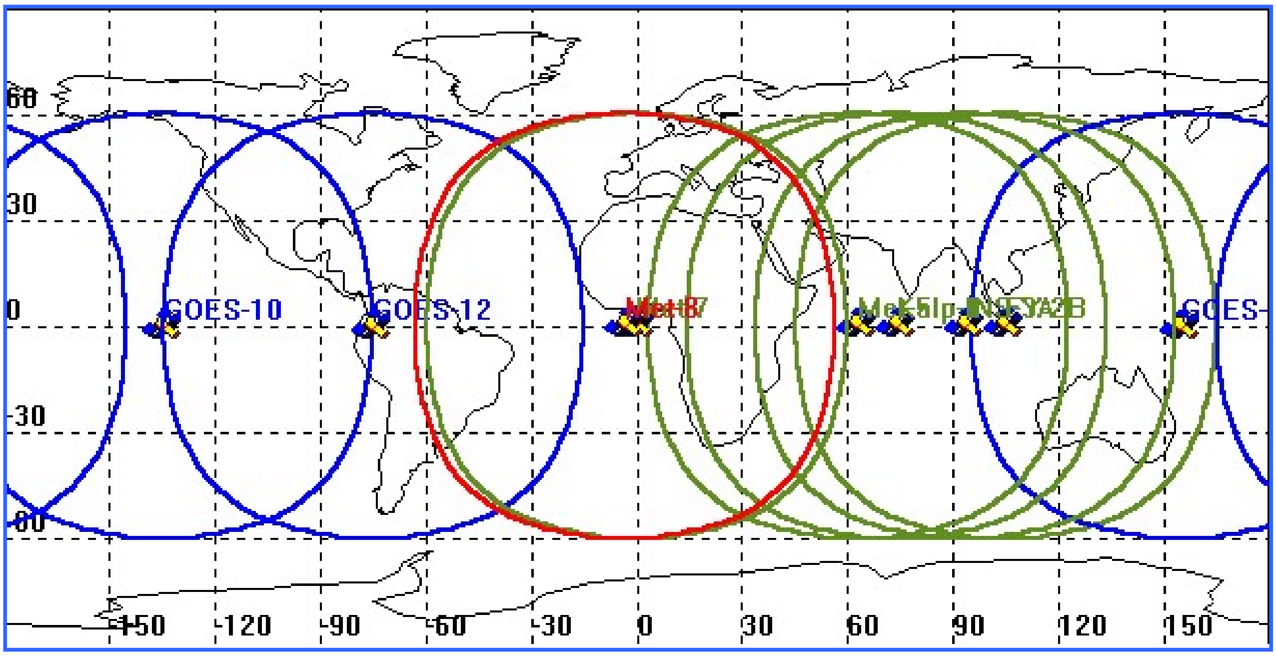


Fig. 2.8.1 – Coverage from operational geostationary satellites as of end 2003. Satellites: GOES-10 (135°W), GOES-12 (75°W), Meteosat-8 (3.4°W), Meteosat-7 (0°), Meteosat-5 (63°E), Kalpana-1 (74°E), INSAT-3A (93.5°E), FY-2B (105°E) and GOES-9 (155°E). Red: advanced imagers (Meteosat-8 SEVIRI); blue: 5 channel imagers (GOES-9/10/12 IMAGER); green: 3 channel imagers (Meteosat-5/7 MVIRI, INSAT-3A VHRR and CCD, Kalpana-1 VHRR).

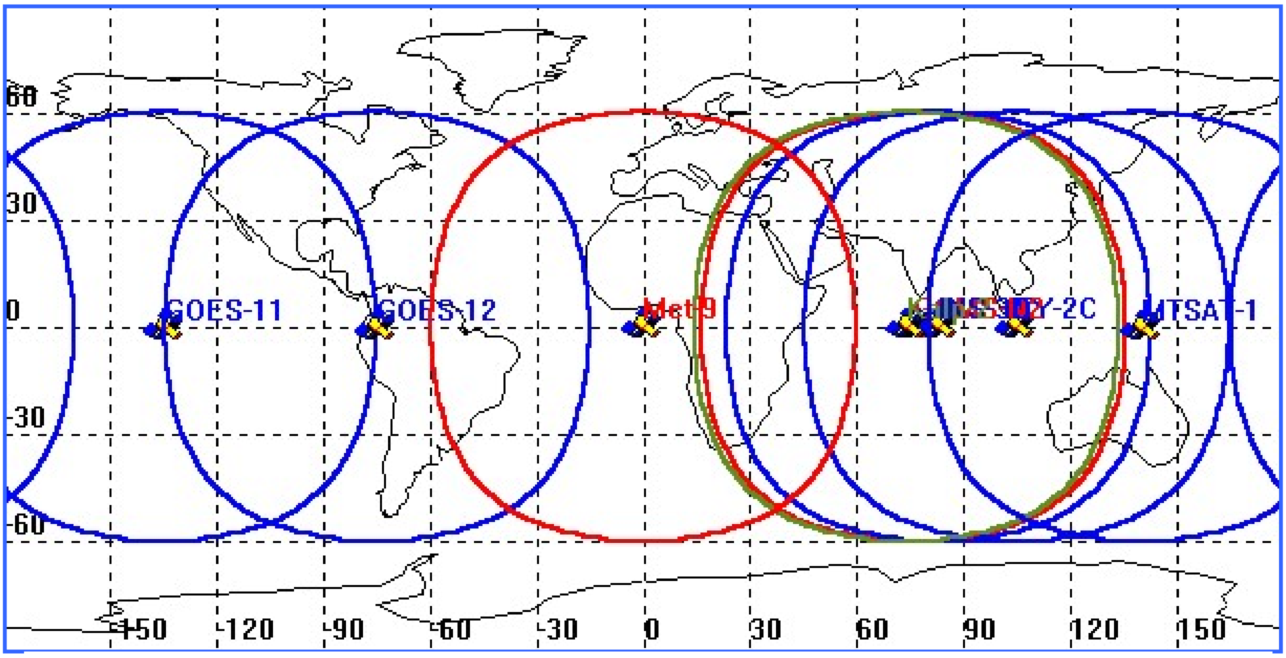


Fig. 2.8.2 – Coverage from operational geostationary satellites as expected in 2006. Satellites: GOES-11 (135°W), GOES-12 (75°W), Meteosat-8 (0°), Kalpana-2 (74°E), GOMS-N2 (76°E), INSAT-3D (83°E), FY-2C (105°E) and MTSAT-1 (140°E). Red: advanced imagers (Meteosat-9 SEVIRI, GOMS-N2 MSU-G); blue: 5-6 channel imagers (GOES 11/12 IMAGER, INSAT-3D IMAGER, FY-2C S-VISSR, MTSAT-1 JAMI); green: 3 channel imagers (Kalpana-2 VHRR).

1.9 Comparative instrument performances

In addition to the coverage, the system also must provide homogeneous performances in terms of data quality, that depends on the instruments. *Table 2.9.1* compares the main features of imagers being operational at end 2003, *Table 2.9.2* refers instead to what is expected in year 2006.

Table 2.9.1 - Main features of imagers on-board GEO satellites at end 2003

Meteosat-8 SEVIRI (*)	**Meteosat-5/7 MVIRI**	**GOES-9/10 IMAGER**	**GOES-12 IMAGER**	**FY-2B S-VISSR**	**INSAT-3A VHRR**	**INSAT-3A CCD**	**Kalpana-1 VHRR**
12.4-14.4 µm			13.0-13.7 µm				
11.0-13.0 µm		11.5-12.5 µm					
9.80-11.8 µm	10.5-12.5 µm	10.2-11.2 µm	10.2-11.2 µm	10.5-11.5 µm	10.5-12.5 µm		10.5-12.5 µm
9.38-9.94 µm							
8.30-9.10 µm							
6.85-7.85 µm							
5.35-7.15 µm	5.70-7.10 µm	6.50-7.00 µm	5.80-7.30 µm	6.30-7.60 µm	5.70-7.10 µm		5.70-7.10 µm
3.40-4.20 µm		3.80-4.00 µm	3.80-4.00 µm				
1.50-1.78 µm						1.55-1.70 µm	
0.74-0.88 µm						0.77-0.86 µm	
0.56-0.71 µm	0.50-0.90 µm	0.55-0.75 µm	0.55-0.75 µm	0.55-1.05 µm	0.55-0.75 µm		0.55-0.75 µm
0.60-0.90 µm						0.63-0.79 µm	
15 min	15 min	30 min	30 min	30 min	180 min	180 min	3 hours
VIS/IR 3.0 km HRVIS 1.0 km	VIS/IR 5.0 km HRVIS 2.5 km	IR 4.0 km VIS 1.0 km	IR 4.0 km VIS 1.0 km	IR 5.76 km VIS 1.44 km	IR 8.0 km VIS 2.0 km	1.0 km	IR 8.0 km VIS 2.0 km

(*) SEVIRI channels are defined as 99 % of encircled energy instead of half-power-width.

Table 2.9.2 - Main features of imagers on-board GEO satellites expected for 2006

Meteosat-9 SEVIRI (*)	**GOES-11 IMAGER**	**GOES-12 IMAGER**	**MTSAT-1 JAMI**	**GOMS-N2 MSU-G**	**FY-2C S-VISSR**	**INSAT-3D IMAGER**	**Kalpana-2 VHRR**
12.4-14.4 µm		13.0-13.7 µm		~13.4 µm			
11.0-13.0 µm	11.5-12.5 µm		11.5-12.5 µm	11.2-12.5 µm	11.5-12.5 µm	11.5-12.5 µm	
9.80-11.8 µm	10.2-11.2 µm	10.2-11.2 µm	10.3-11.3 µm	10.2-11.2 µm	10.3-11.3 µm	10.2-11.2 µm	10.5-12.5 µm
9.38-9.94 µm				9.20-10.2 µm			
8.30-9.10 µm				8.20-9.20 µm			
6.85-7.85 µm				7.50-8.50 µm			
5.35-7.15 µm	6.50-7.00 µm	5.80-7.30 µm	6.50-7.00 µm	5.70-7.00 µm	6.30-7.60 µm	6.50-7.00 µm	5.70-7.10 µm
3.40-4.20 µm	3.80-4.00 µm	3.80-4.00 µm	3.50-4.00 µm	3.50-4.00 µm	3.50-4.00 µm	3.80-4.00 µm	
1.50-1.78 µm				~ 1.6 µm		1.55-1.70 µm	
0.74-0.88 µm				0.80-0.90 µm			
0.56-0.71 µm	0.55-0.75 µm	0.55-0.75 µm	0.55-0.90 µm	0.65-0.80 µm	0.55-0.99 µm	0.52-0.72 µm	0.55-0.75 µm
0.60-0.90 µm				0.50-0.65 µm			
15 min	30 min	30 min	60 min	30 min	30 min	30 min	3 hours
VIS/IR 3.0 km HRVIS 1.0 km	IR 4.0 km VIS 1.0 km	IR 4.0 km VIS 1.0 km	IR 4.0 km VIS 1.0 km	IR 4.0 km VIS/NIR 1.0km	IR 5.0 km VIS 1.25 km	IR 4km,WV 8km VIS/NIR 1.0km	IR 8.0 km VIS 2.0 km

(*) SEVIRI channels are defined as 99 % of encircled energy instead of half-power-width.

Three categories of instruments can be identified:

- with 3 channels and relatively coarse space-time resolution: Kalpana-2/VHRR
- with 5-6 channels: GOES-12/IMAGER, MTSAT-1/JAMI, FY-2C/S-VISSR, INSAT-3D/IMAGER;
- advanced imagers with pseudo-sounding capability: Meteosat-8/SEVIRI and GOMS-N2/MSU-G.

In Fig. 2.8.1 and Fig. 2.8.2 the coverage from images of different classes is highlighted by different colours. It is noted that at end-2003 there is lack of quality in Central Asia / Indian Ocean, whereas in 2006 this gap will be filled.

2. Sunsynchronous satellites

2.1 Generalities

At the time of the First GARP Global Experiment (FGGE, 1979-80) the WMO requirement for sunsynchronous satellites was two satellites with orthogonal orbital planes. For large-swath instruments with day and night capability this would ensure global coverage at 6-hour intervals. In the 90's, the EUMETSAT and NOAA agreement for a Joint Polar System (JPS) was aiming at three satellites with orbital planes de-phased by 60° so as to achieve global coverage at 4-hour intervals. In 2002 the WMO requirement has been increased to four satellites, two in morning orbits and two in afternoon orbits, so as to provide global coverage at 3-hour intervals in average, and also to ensure that sufficient contingency margins exist in case one of the satellites experiences degraded performance, waiting for the replacement.

The mission of sunsynchronous satellites is, as a minimum:

- to provide temperature and humidity global sounding for the purpose of NWP;
- to provide imagery mission to high latitudes inaccessible to geostationary satellites.

Several satellites provide more than this. Some provide observation of ozone and other trace gases, some exploit microwave radiometry for precipitation observation, some carry active microwave instruments (radar) for, e.g., sea-surface wind observation, etceteras. In addition, several products are derived by image processing, specifically surface parameters. The Extraordinary Session of CBS in Cairns, Australia, 4-12 December 2002, solicited Members to improve and augment the payload instruments of sunsynchronous satellites by replacing IR sounding radiometers with spectrometers for improved profile's vertical resolution, to exploit radio-occultation sounding, to introduce operational radar altimeters and to extend the use of MW for both passive imagery and radar scatterometry.

2.2 The NOAA/POES programme

The American ***POES (Polar-orbiting Operational Environmental Satellite)***, when considering the precursor series TIROS, ESSA and ITOS, is the most long-standing meteorological satellite programme (first launch: 1° April 1960). It evolved through the following phases.

- 1st generation – Ten satellites ***TIROS (Television and Infra-Red Observation Satellite)***, spin-stabilised (***Fig. 3.2.1***), to experience orbits, instruments and communication systems. Instruments:
  - VCS (Vidicon Camera System) with Narrow-Angle (NA) and high resolution (0.25 km), Medium-Angle (MA) and resolution (1.6 km), Wide-Angle (WA) and low resolution (2.4 km);
  - APT (Automatic Picture Transmission), resolution 1.8 km;
  - MRIR (Medium Resolution Infrared Radiometer) and FPR (Flat Plate Radiometer)
- 2nd generation – Nine satellites ***ESSA (Environmental Science and Services Administration)***, two in orbit at any time (***TOS, TIROS Operational System***) for image broadcasting either in real time (ESSA-2/4/6/8) or after on-board storage (ESSA-1/3/5/7/9). They were spin-stabilised in a "cartwheel" mode so as to be able to point the camera towards Earth (***Fig. 3.2.2***). Instruments:
  - on ESSA-2/4/6/8: APT (Automatic Picture Transmission), resolution 3.7 km;
  - on ESSA-1/3/5/7/9: AVCS (Advanced Vidicon Camera System), resolution 3.7 km, and FPR.
- 3rd generation – Six satellites ***ITOS (Improved TOS)***, the first named TIROS-M or ITOS-1, the other ones ***NOAA (National Oceanic and Atmospheric Administration)*** (***Fig. 3.2.3***). They introduced IR imagery and temperature sounding. 3-axis stabilised. Instruments:
  - SR (Scanning Radiometer): 0.55-0.75 µm, resolution 3.6 km, and 10.5-12.5 µm, 7.2 km;
  - VHRR (Very High Resolution Radiometer): same channels as SR but with resolution 0.9 km;
  - VTPR (Vertical Temperature Profile Radiometer): 8 channels, 11 to 20 µm, resolution 55 km;
  - SPM (Solar Proton Monitor) and FPR;
- 4th generation – Ten operational satellites, the first named TIROS-N, the following nine ***NOAA*** from 6 to 14, with an improvement (***ATN, Advanced TIROS-N***) starting from NOAA-8. Two satellites in orbit at any time, with LST (Local Solar Time) at 7.30 and 14.00. 3-axis-stabilised. Instruments:
  - AVHRR (Advanced VHRR): see next
  - HIRS/2 (High-resolution Infra Red Sounder): see next
  - MSU (Microwave Sounding Unit): 4 channels from 50 to 58 GHz, resolution 110 km
  - SSU (Stratospheric Sounding Unit): three channels around 14.95 µm, resolution 150 km
  - SBUV/2 (Solar Backscatter Ultraviolet): see next
  - ERBE (Earth Radiation Budget Experiment): only on NOAA-9 and NOAA-10
  - SEM (Space Environment Monitor), SARSAT (Search and Rescue Satellite Aided Tracking System), ARGOS/DCS (ARGOS Data Collection System); see next.
- 5th generation, the current one, now called ***POES (Polar-orbiting Operational Environmental Satellite)***, started in 1998 with NOAA-15, to be used until around 2012 by five flight models (NOAA-K/L/M/N/N'). POES satellites (***Fig. 3.2.4***) still use the 3-axis stabilised ATN platform and are in orbit two at any time, at LST 7.30 and 14.00. The difference between the 4th and 5th generations consists of the improvement of the instrumentation for MW atmospheric sounding.

Table 3.2.1 records the chronology of NOAA and precursor satellites. For sunsynchronous satellites (starting with TIROS-9) the LST is provided, for previous the orbital inclination. Morning LSTs are defined at the equatorial descending node, afternoon at the ascending node.

At the end of 2003, the two nominal operational satellites are NOAA-16 and NOAA-17, with NOAA-15 still sufficiently efficient as to act as backup. NOAA-11 and NOAA-12 still have some functionalities (NOAA-11: SSU, Argos and SARSAT; NOAA-12: AVHRR, SEM and Argos); NOAA-14, the last satellite of the 4th generation, still has HIRS/2, MSU, SSU, SEM, Argos and SARSAT operable.

Table 3.2.1 – Chronology of the NOAA/POES programme (in bolt the satellites active at end 2003)

Satellite	Launch	End of service	Height	LST or inclin.	Status (Dec 2003)	Instruments
TIROS-1	1 Apr 1960	17 Jun 1960	720 km	48.4°	Inactive	VCS-WA, VCS-NA
TIROS-2	23 Nov 1960	24 Dec 1961	670 km	48.6°	Inactive	VCS-WA, VCS-NA, MRIR, FPR
TIROS-3	12 Jul 1961	27 Feb 1962	780 km	47.9°	Inactive	2 x VCS-WA, MRIR, FPR
TIROS-4	8 Feb 1962	19 Jul 1962	770 km	48.3°	Inactive	VCS-WA, VCS-MA, MRIR, FPR
TIROS-5	19 Jun 1962	27 Nov 1963	750 km	58.1°	Inactive	VCS-WA, VCS-MA
TIROS-6	18 Sep 1962	12 Oct 1963	700 km	58.3°	Inactive	VCS-WA, VCS-MA
TIROS-7	19 Jun 1963	3 Jun 1968	680 km	58.2°	Inactive	2 x VCS-WA, MRIR, FPR
TIROS-8	21 Dec 1963	1 Jul 1967	730 km	58.5°	Inactive	APT, VCS-WA
TIROS-9	22 Jan 1965	12 Jun 1968	1350 km	9.30	Inactive	2 x VCS-WA (“cartwheel”)
TIROS-10	2 Jul 1965	1 Jul 1967	790 km	9.30	Inactive	2 x VCS-WA
ESSA-1	3 Feb 1966	8 Mar 1967	770 km	9.30	Inactive	2 x VCS-WA, FPR
ESSA-2	28 Feb 1966	16 Oct 1970	1390 km	9.30	Inactive	2 x APT
ESSA-3	2 Oct 1966	2 Dec 1968	1440 km	9.30	Inactive	2 x AVCS, FPR
ESSA-4	26 Jan 1967	5 May 1968	1380 km	9.30	Inactive	2 x APT
ESSA-5	20 Apr 1967	20 Feb 1970	1390 km	9.30	Inactive	2 x AVCS, FPR
ESSA-6	10 Nov 1967	3 Dec 1969	1450 km	9.30	Inactive	2 x APT
ESSA-7	16 Aug 1968	10 Mar 1970	1450 km	9.30	Inactive	2 x AVCS, 2 x FPR
ESSA-8	15 Dec 1968	12 Mar 1976	1440 km	9.30	Inactive	2 x APT
ESSA-9	26 Feb 1969	15 Nov 1972	1470 km	9.30	Inactive	2 x AVCS, 2 x FPR
ITOS-1 (TIROS-M)	23 Jan 1970	18 Jun 1971	1470 km	14.30	Inactive	2 x AVCS, 2 x APT, 2 x SR, FPR, SPM
NOAA-1 (ITOS-A)	11 Dec 1970	19 Aug 1971	1450 km	13.30	Inactive	2 x AVCS, 2 x APT, 2 x SR, FPR, SPM
NOAA-2 (ITOS-D)	13 Oct 1972	30 Jan 1975	1450 km	14.30	Inactive	2 x VHRR, 2 x SR, 2 x VTPR, SPM
NOAA-3 (ITOS-F)	6 Nov 1973	31 Aug 1976	1500 km	14.30	Inactive	2 x VHRR, 2 x SR, 2 x VTPR, SPM
NOAA-4 (ITOS-G)	15 Nov 1974	18 Nov 1978	1450 km	14.30	Inactive	2 x VHRR, 2 x SR, 2 x VTPR, SPM
NOAA-5 (ITOS-H)	29 Jul 1976	16 Jul 1979	1510 km	14.30	Inactive	2 x VHRR, 2 x SR, 2 x VTPR, SPM
TIROS-N	13 Oct 1978	27 Feb 1981	850 km	14.30	Inactive	AVHRR, HIRS/2, MSU, SSU, SEM, Argos
NOAA-6	27 Jun 1979	31 Mar 1987	840 km	07.30	Inactive	AVHRR, HIRS/2, MSU, SSU, SEM, Argos
NOAA-7	23 Jun 1981	7 Jun 1986	860 km	14.30	Inactive	AVHRR, HIRS/2, MSU, SSU, SEM, Argos
NOAA-8	28 Mar 1983	29 Dec 1985	820 km	07.30	Inactive	AVHRR, HIRS/2, MSU, SSU, SEM, Argos, SARSAT
NOAA-9	12 Dec 1984	13 Feb 1998	850 km	14.30	Inactive	AVHRR, HIRS/2, MSU, SSU, SEM, Argos, SARSAT, ERBE, SBUV/2
NOAA-10	17 Sep 1986	30 Aug 2001	810 km	07.30	Inactive	AVHRR, HIRS/2, MSU, SSU, SEM, Argos, SARSAT, ERBE, SBUV/2
NOAA-11	24 Sep 1988	expected ≥ 2004	843 km	14.15	Limited use	AVHRR, HIRS/2, MSU, SSU, SEM, Argos, SARSAT, SBUV/2
NOAA-12	14 May 1991	expected ≥ 2004	808 km	04.40	Limited use	AVHRR, HIRS/2, MSU, SSU, SEM, Argos
NOAA-13	9 Aug 1993	21 Aug 1993	820 km	14.00	Inactive	AVHRR, HIRS/2, MSU, SSU, SEM, Argos, SARSAT, SBUV/2
NOAA-14	30 Dec 1994	expected ≥ 2004	847 km	07.40	Limited use	**AVHRR/2, HIRS/2, MSU, SSU, SEM, Argos, SARSAT, SBUV/2**
NOAA-15	**13 May 1998**	**expected ≥ 2004**	**810 km**	**06.30**	**Backup**	**AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SEM/2, Argos, SARSAT**
NOAA-16	**21 Sep 2000**	**expected ≥ 2005**	**851 km**	**14.15**	**Operational**	**AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2,SEM/2, Argos, SARSAT**
NOAA-17	**24 Jun 2002**	**expected ≥ 2006**	**812 km**	**10.20**	**Operational**	**AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2,SEM/2, Argos, SARSAT**
NOAA-18 (NOAA-N)	2004	expected ≥ 2008	840 km	14.00	Close to launch	AVHRR/3, HIRS/3, AMSU-A, MHS, SBUV/2,SEM/2, Argos, SARSAT
NOAA-19 (NOAA-N’)	2008	expected ≥ 2012	840 km	14.00	Being built	AVHRR/3, HIRS/3, AMSU-A, MHS, SBUV/2,SEM/2, Argos, SARSAT

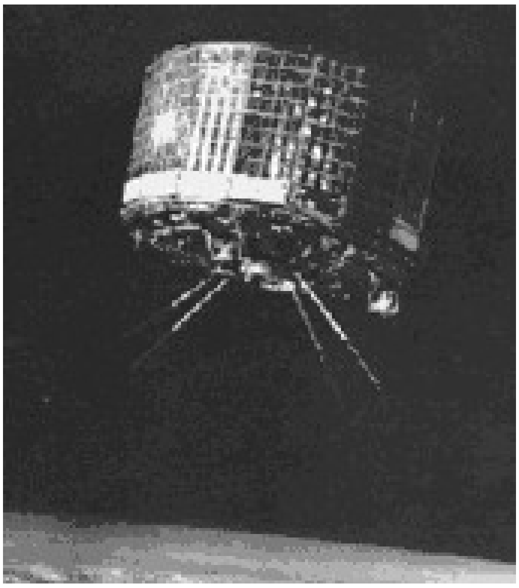


Fig. 3.2.1 – View of TIROS (spin-stabilised).

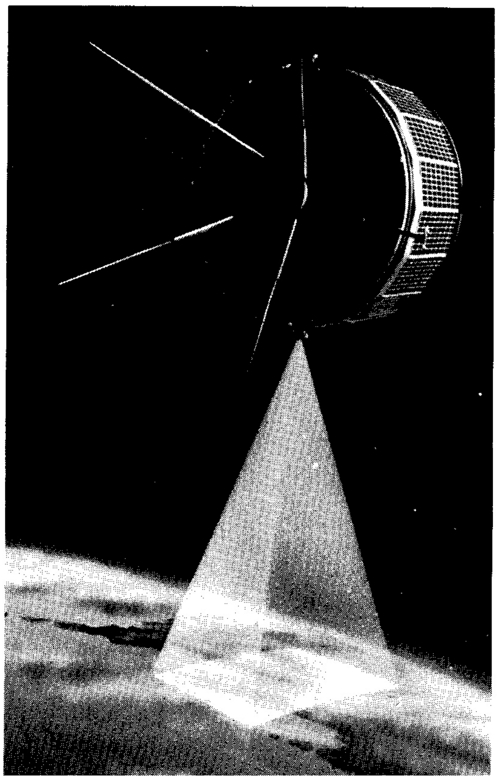


Fig. 3.2.1 – View of ESSA ("cartwheel" spin- stabilised).

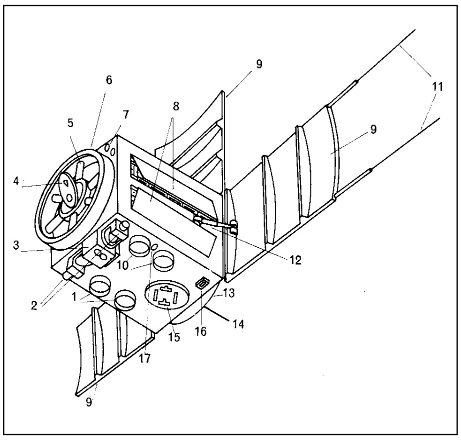


Fig. 3.2.3 – Sketch view of ITOS (first 3-axis stabilised of the POES series).

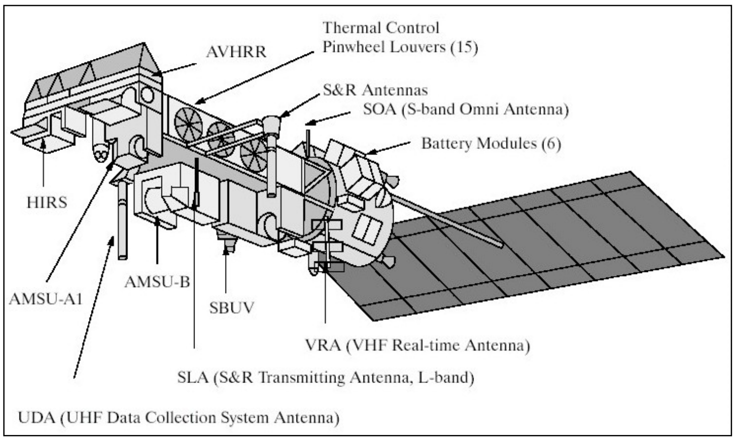


Fig. 3.2.4 – Sketch view of NOAA (K, L, M series).

NOAA-15

Launched in May 1998, it is the first satellite of the 5th generation, that replaces the sounding package TOVS (TIROS Operational Vertical Sounding = HIRS/2 + MSU + SSU), by ***ATOVS (Advanced TOVS = HIRS/3 + AMSU-A + AMSU-B)***. Some instruments currently are defective, but still NOAA-15 could backup NOAA-17 in case of problems.

NOAA-16

Launched in September 2000, it is the current operational satellite in the afternoon orbit. Unfortunately, its VHF transmitter for APT has failed.

NOAA-17

Launched in June 2002, it is the last NOAA satellite in the morning orbit. Further NOAA satellites (NOAA-N and NOAA-N') will be focusing on the afternoon orbit.

Payload of the 5th generation NOAA satellites (NOAA-15 onwards)

- ***AVHRR/3 (Advanced VHRR)***: 6-channel VIS/IR radiometer for multi-purpose imagery with 1.1 km resolution and 2900 km swath. Only 5 channels transmitted (1.6 µm and 3.7 µm are alternative, day and night respectively). See the instrument sheet in Appendix.
- ***HIRS/3 (High-resolution Infra Red Sounder - 3)***: 20-channels IR radiometer (including one VIS) for temperature/humidity sounding, resolution 18 km and swath 2250 km. See the instrument sheet in Appendix.
- ***AMSU-A (Microwave Sounding Unit - A)***: 15-channel MW radiometer for nearly-all-weather temperature sounding, resolution 48 km, swath 2250 km. See the instrument sheet in Appendix.
- ***AMSU-B (Microwave Sounding Unit - B)***: 5-channel MW radiometer for nearly-all-weather humidity sounding, resolution 16 km, swath 2250 km. To be replaced on NOAA-N and NOAA-N' by ***MHS (Microwave Humidity Sounder)***. See the instrument sheets in Appendix.
- ***SBUV/2 (Solar Backscatter Ultraviolet - 2)***: 12-channel UV spectro-radiometer for ozone profiling, resolution 170 km, nadir-only viewing. See the instrument sheet in Appendix.
- ***SEM/2 (Space Environment Monitor)***, an instrument suite for *in situ* measurement of the energy of charged particle of the solar wind at orbital height (not on NOAA-15).
- ***DCS/2 (Data Collection System – 2)***, also know as ***Argos***, to collect data from automatic stations and localise the platform. Platform transmission frequency: 401.65 MHz.
- ***SARSAT (Search and Rescue Satellite Aided Tracking System)***, location system for emergency calls from transmitters at 121.5 or 243 or 406 MHz.

Data transmission from NOAA satellites

The totality of the information from NOAA instruments is transmitted in real time, and only part is stored on board for successive transmission to:

- Command and Data Acquisition stations (CDA) in charge of global data recovery. Main features:
  - frequencies: 1702.5 MHz (left-hand circular polarisation) and 1698 or 1707 MHz (right-hand circular polarisation); bandwidth .... MHz, data rate 2.66 Mbps;
  - GAC (Global Area Coverage) all data from low-bit-rate instruments at full resolution and AVHRR images with resolution reduced to 4 km, for the full orbit (102 min);
  - LAC (Local Area Coverage) for up to 11 min of selected AVHRR full resolution image frames.

There are three types of transmission with different contents for different ground receiving stations.

- ***HRPT (High Resolution Picture Transmission)***, for the whole information at full resolution in digital form at S-band frequencies. Main features:
  - frequencies: 1698 or 1707 MHz; bandwidth: 2.66 MHz; polarisation: right hand circular (backup: 1702.5 MHz, polarisation left hand circular)
  - antenna diameter ~ 2 m, G/T ~ 6.0 dB/K, data rate 665.4 kbps;
- ***APT (Automatic Picture Transmission)***, for two image channels at reduced resolution (4 km) with correction of the panoramic distortion, in analogue form at VHF frequencies. Main features:
  - frequencies: 137.5 or 137.62 MHz; bandwidth: 34 kHz; polarisation: right hand circular
  - omni-directional antenna, G/T ~ -30 dB/K, base band 2.1 kHz (analogue);
- ***DSB (Direct Sounder Broadcast)***, for low-bit instruments (but not AMSU), in digital form at VHF frequencies. Main features:
  - frequencies: 137.35 or 137.77 MHz; bandwidth: ...... kHz; polarisation: right hand circular
  - antenna: ...., G/T ~ .... dB/K, data rate 8.32 kbps.

2.3 The DMSP programme (limited to MW sensors supportive of GOS)

Strictly speaking, the ***DMSP (Defense Meteorological Satellite Program)*** is not part of the GOS, but data from the Special Sensors in Microwave (SSM) are distributed from NOAA either to make up for the lack of MW imagers on NOAA satellites, or as a backup to the MW temperature/humidity sounders.

DMSP is a 3-axis stabilised satellite using the same platform as current NOAA satellites (see again Fig. 3.2.4). The DoD (Department of Defense) uses to have two satellites in orbit at any time, with LST 5.30 and 7.30 respectively. Table 3.3.1 records the chronology of the DMSP limited to the period since the introduction of the SSM instruments.

Table 3.3.1 – Chronology of the DMSP/SSM programme *(in bolt the satellites active at end 2003)*

Satellite	Launch	End of service	Height	LST	Status (Dec 2003)	MW instruments
DMSP-F04	6 Jun 1979	29 Aug 1980	850 km	????	Inactive	SSM/T
DMSP-F07	18 Dec 1983	17 Oct 1987	850 km	????	Inactive	SSM/T
DMSP-F08	18 Jun 1987	13 Aug 1991	850 km	06.05	Inactive	SSM/I, SSM/T
DMSP-F09	3 Feb 1988	????	850 km	????	Inactive	SSM/T
DMSP-F10	1 Dec 1990	14 Nov 1997	850 km	10.20	Inactive	SSM/I, SSM/T
DMSP-F11	28 Nov 1991	16 May 2000	850 km	07.30	Inactive	SSM/I, SSM/T, SSM/T-2
DMSP-F12	29 Aug 1994	31 Jul 2002	850 km	05.45	Inactive	SSM/T, SSM/T-2
DMSP-F13	**24 Mar 1995**	**expected ≥ 2004**	**850 km**	**06.25**	**Operational**	**SSM/I, SSM/T**
DMSP-F14	**4 Apr 1997**	**expected ≥ 2004**	**852 km**	**07.40**	**Backup**	**SSM/I, SSM/T, SSM/T-2**
DMSP-F15	**12 Dec 1999**	**expected ≥ 2005**	**850 km**	**09.15**	**Operational**	**SSM/I, SSM/T, SSM/T-2**
DMSP-F16	18 Oct 2003	expected ≥ 2007	833 km	08.00	Commissioned	SSMIS
DMSP-F17	2004	expected ≥ 2008	833 km	05.30	Close to launch	SSMIS
DMSP-F18	2006	expected ≥ 2010	833 km	08.00	Being built	SSMIS
DMSP-F19	2008	expected ≥ 2012	833 km	05.30	Planned	SSMIS
DMSP-F20	2010	expected ≥ 2014	833 km	05.30	Planned	SSMIS

NOAA acquires and distribute (on request) data from the following instruments:

- ***SSM/I (Special Sensor Microwave / Imager)***, for precipitation rate, sea-surface wind speed and sea ice; 4-frequency / 7-channel radiometer (double polarisation for three frequencies); conical scanning with resolution between 13 km at 85 GHz and 55 km at 19 GHz; useful swath 1400 km. See the instrument sheet in Appendix.
- ***SSM/T (Special Sensor Microwave / Temperature)***, for nearly-all-weather temperature sounding; 7-channel radiometer operating in the 54 GHz band, resolution 200 km, cross-track scanning, 1500 km swath. See the instrument sheet in Appendix.
- ***SSM/T-2 (Special Sensor Microwave / Humidity)***, for nearly-all-weather humidity sounding; 5-channel radiometer operating in the 183 GHz band, resolution 48 km, cross-track scanning, 1500 km swath. See the instrument sheet in Appendix.

Starting with DMSP-F16, SSM/I, SSM/T and SSM/T-2 are progressively being replaced by:

- ***SSMIS (Special Sensor Microwave / Imager/Sounder)***, a 21-frequency / 24 channel radiometer (double polarisation for three frequencies); conical scanning with resolution between 13 km in the range 50-190 GHz and 55 km at 19 GHz; nominal swath 1700 km, useful 1400 km. See the instrument sheet in Appendix.

2.4 The NPOESS programme

As shown in Tables 3.2.1 and 3.3.1, the NOAA programme foresees the last launch in 2008 and DMSP in 2010. This is because the civilian NOAA and the military DMSP are due to merge into ***NPOESS (National Polar-orbiting Operational Environmental Satellite System)***. NPOESS (***Fig. 3.4.1***) is based on three satellites with LST 5.30, 9.30 and 13.30 respectively. The 9.30 satellite will carry a limited number of instruments, since it is coordinated, on the same orbit, with the European MetOp (see next). To reduce the risks associated to newly-developed instruments, an ***NPP (NPOESS Preparatory Project)*** will precede the series. ***Table 3.4.1*** records the currently envisaged chronology of NPOESS, also showing that satellites in different orbits may carry different instruments.

Table 3.4.1 – Chronology of the NPOESS program *(instrument distribution not consolidated)*

Satellite	Launch	End of service	Height	LST	Status (Dec 2003)	Instruments
NPP	May 2006	expected ≥ 2011	824 km	10.30	Being built	VIIRS, CrIS, ATMS, OMPS
NPOESS-1	Nov 2009	expected ≥ 2016	833 km	9.30	Planned	VIIRS, CMIS, APS, SARSAT
NPOESS-2	Jun 2011	expected ≥ 2018	833 km	13.30	Planned	VIIRS, CrIS, ATMS, CMIS, OMPS, GPSOS, SESS, ERBS, A-DCS, SARSAT
NPOESS-3	Jun 2013	expected ≥ 2020	833 km	5.30	Planned	VIIRS, CrIS, ATMS, CMIS, TSIS, ALT, A-DCS, SARSAT
NPOESS-4	Nov 2015	expected ≥ 2022	833 km	9.30	Planned	VIIRS, CMIS, APS, SARSAT
NPOESS-5	Jan 2018	expected ≥ 2025	833 km	13.30	Planned	VIIRS, CrIS, ATMS, CMIS, OMPS, GPSOS, SESS, ERBS, A-DCS, SARSAT
NPOESS-6	2019	expected ≥ 2026	833 km	5.30	Planned	VIIRS, CrIS, ATMS, CMIS, TSIS, ALT, A-DCS, SARSAT

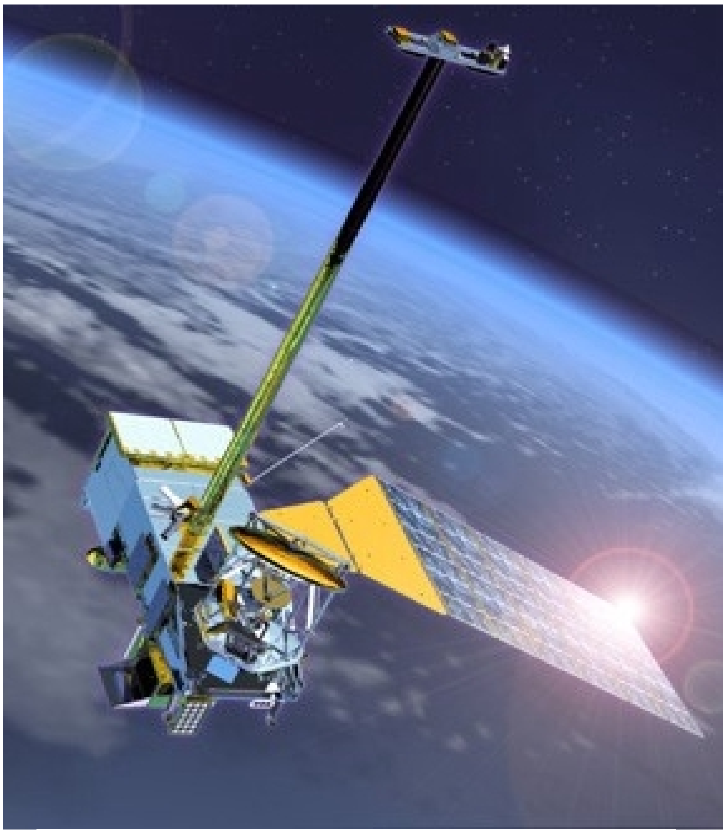


Fig. 3.4.1 – View of NPOESS.

Main payload of NPOESS

Not all instruments of NPOESS have been fully consolidated. The following is known as of end-2003.

- ***VIIRS (Visible/Infrared Imager Radiometer Suite)***, the successor of AVHRR: 22-channel VIS/IR radiometer for multipurpose imagery; resolution 400 m for four AVHRR-like channels and one day-night VIS channel, and 800 m for the remaining 17 channels; swath 3000 km. See the instrument sheet in Appendix.
- ***CrIS (Cross-track Infrared Sounder)***, the successor of HIRS/4, actually a totally different instrument based on an IR interferometer to provide high-vertical-resolution temperature/humidity sounding; 1302 channels with spectral resolution 0.625 to 2.5 cm^{-1}, resolution 14 km, swath 2200 km. See the instrument sheet in Appendix.
- ***ATMS (Advanced Technology Microwave Sounder)***, the successor of AMSU-A and AMSU-B for nearly-all-weather temperature and humidity sounding; 22-channel MW radiometer with bands at 54 and 183 GHz, resolution 16 km at 183 GHz and 32 km at 54 GHz, swath 2200 km. See the instrument sheet in Appendix.
- ***CMIS (Conical-scanning Microwave Imager/Sounder)***, the successor of the DMSP SSMIS for multi-purpose MW imagery and supporting temperature/humidity sounding; 63 frequencies, 77 channels (3 with double polarisation, 2 with four polarisations and 1 with six polarisations); resolution from 3 km at 89 GHz to 40 km at 6.6 GHz, swath 1700 km nominal (conical scanning), 1400 km useful. See the instrument sheet in Appendix.
- ***OMPS (Ozone Mapping and Profiler Suite)***, the successor of SBUV/2, that adds to the nadir-view (best for vertical profile of ozone) the cross-track scanning capability (swath 2800 km) for total ozone mapping and limb sounding for high-vertical-resolution in the stratosphere. Resolution 250 km (profiler), 50 km (mapper), 1-km vertical (limb). See the instrument sheet in Appendix.
- ***GPSOS (Global Positioning System Occultation Sensor)***, for all-weather very-high-vertical resolution temperature and humidity profile by observing the phase delay of GPS signals received during the occultation phase. 0.5-1 km vertical resolution, ~ 300 km horizontal resolution; 500 measurements/day. See the instrument sheet in Appendix.
- ***APS (Aerosol Polarimetry Sensor)***, for tropospheric aerosol observation: 9-channel VIS/NIR/SWIR polarimeter scanning along-track within ± 60° and measuring polarisations at 0, 45, 90 and 135° to get the four Stokes components. Resolution 10 km. See the instrument sheet in Appendix.
- ***ERBS (Earth Radiation Budget Sensor)***, successor of ERBE and of CERES (Clouds and the Earth's Radiant Energy System), being flown on TRMM and EOS Terra/Aqua; 3 channels (two broad-band, one narrow), resolution 20 km, swath 3000 km. See the instrument sheet in Appendix.
- ***ALT (Radar Altimeter)***, derived from Jason-1, for ocean topography and wave height; two frequencies, resolution 25 km, nadir-viewing. See the instrument sheet in Appendix.
- ***SESS (Space Environment Sensor Suite)***, successor of SEM/2 for *in situ* measurements of charged particles of the solar wind.
- ***TSIS (Total Solar Irradiance Sensor)***, for total irradiance and the fraction in the 0.2-2.0 µm range.
- ***A-DCS (ARGOS Data Collection System)***, successor of DCS/2, with the additional capability of sending messages to the Data Collection Platform for the purpose of changing its configuration.
- ***SARSAT (Search and Rescue Satellite Aided Tracking System)***, successor of previous one except that only the 406 MHz will be retained.

Data transmission from NPP and NPOESS

The full information from all instruments is stored on board and transmitted in Ka-band to a number of ground stations, according to the standard:

- ***SMD (Stored Mission Data)***, frequency 25.65 GHz, bandwidth 300 MHz, data rate 150 Mbps.

Direct read-out is provided according to two systems, both digital:

- ***HRD (High Rate Data)***, for full information in X-band. Main features:
  - frequencies: 7812 or 7830 MHz; bandwidth: 30.8 MHz; polarisation: right hand circular
  - antenna diameter ~ 2 m, G/T ~ .... dB/K, data rate 20 Mbps;
- ***LRD (Low Rate Data)*** for selected information in S-band. Main features:
  - frequency: 1706 MHz; bandwidth: 8 MHz; polarisation: right hand circular-
  - antenna diameter ~ 1 m, G/T ~ .... dB/K, data rate 3.88 Mbps

NPP will only use the HRD standard. The data rate will be 15 Mbps.

2.5 The EPS/MetOp programme

The European ***EPS (EUMETSAT Polar System)*** draws its origins from the 80's, when the USA decided to reduce their involvement in the morning orbit for focusing on the afternoon one. ESA started with studying a very large satellite, called POEM (Polar Orbit Earth-observation Mission), based on the 3-axis stabilised "Polar Platform", another ESA programme. Thereafter (1993) the POEM mission was split in two missions: ENVISAT, focusing on science and environment, and ***MetOp***, designed for operational meteorology to implement the EPS programme. Three MetOp flight models (***Fig. 3.5.1***) are being built. ***Table 3.5.1*** records the chronology of the MetOp/EPS programme.

Table 3.5.1 – Chronology of the first three satellites (MetOp) of the EPS programme

Satellite	Launch	End of service	Height	LST	Status (Dec 2003)	Instruments
MetOp-1	Jun 2005	expected ≥ 2010	827 km	9.30	Buing built	AVHRR/3, HIRS/4, AMSU-A, MHS, IASI, GOME-2, GRAS, ASCAT, SEM/2, Argos, SARSAT
MetOp-2	Jun 2010	expected ≥ 2015	827 km	9.30	Buing built	AVHRR/3, HIRS/4, AMSU-A, MHS, IASI, GOME-2, GRAS, ASCAT, SEM/2, Argos, SARSAT
MetOp-3	Dec 2014	expected ≥ 2020	827 km	9.30	Buing built	Imager TBD (VIRI-M), AMSU-A or AMTS, MHS, IASI, GOME-2, GRAS, ASCAT, SEM/2, Argos, SARSAT

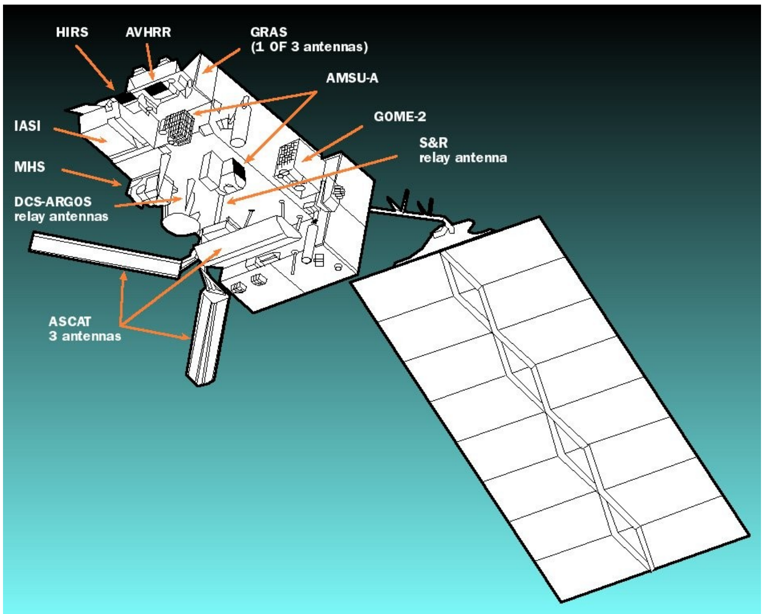


Fig. 3.5.1 – Sketch view of MetOp.

Payload of MetOp/EPS

- ***AVHRR/3 (Advanced VHRR)***: 6-channel VIS/IR radiometer for multi-purpose imagery with 1.1 km resolution and 2900 km swath. Only 5 channels transmitted (1.6 µm and 3.7 µm are alternative, day and night respectively). Probably not on MetOp-3. See the instrument sheet in Appendix.
- ***HIRS/4 (High-resolution Infra Red Sounder - 4)***: 20-channels IR radiometer (including one VIS) for temperature/humidity sounding, resolution 10 km and swath 2250 km. Not on MetOp-3. See the instrument sheet in Appendix.

- ***AMSU-A (Microwave Sounding Unit - A)***: 15-channel MW radiometer for nearly-all-weather temperature sounding, resolution 48 km, swath 2250 km. Probably not on MetOp-3. See the instrument sheet in Appendix.
- ***MHS (Microwave Humidity Sounder)***: 5-channel MW radiometer for nearly-all-weather humidity sounding, resolution 16 km, swath 2250 km. See the instrument sheets in Appendix.
- ***IASI (Infrared Atmospheric Sounding Interferometer)***: IR interferometer to provide high-vertical-resolution temperature/humidity sounding; 8460 channels with spectral resolution 0.25 cm^{-1}, resolution 12 km, swath 2050 km. See the instrument sheet in Appendix.
- ***GOME-2 (Global Ozone Monitoring Experiment – 2)***, follow-on of the ERS-2 GOME: 4096-channel UV/VIS grating spectrometer (plus 200 polarisation channels) for ozone (total-column and profile) and other trace species (generally total-column); resolution 40 km for a 960 km swath or 80 km for a 1920 km swath. See the instrument sheet in Appendix.
- ***GRAS (GNSS Receiver for Atmospheric Sounding)***, for all-weather very-high-vertical resolution temperature and humidity profile by observing the phase delay of GPS signals received during the occultation phase. 0.5-1 km vertical resolution, ~ 300 km horizontal resolution; 500 measurements/day. See the instrument sheet in Appendix.
- ***ASCAT (Advanced Scatterometer)***, follow-on of the ERS 1/2 radar scatterometer for sea-surface wind:. Frequency 5.255 GHz, resolution 25 km, two side swaths of 500 km each with a 700-km gap along track. See the instrument sheet in Appendix.
- ***SEM/2 (Space Environment Monitor)***, an instrument suite for *in situ* measurement of the energy of charged particle of the solar wind at orbital height.
- ***DCS (Data Collection System)***, also know as ***Argos***, to collect data from automatic stations and localise the platform. Platform transmission frequency: 401.65 MHz.
- ***SARSAT (Search and Rescue Satellite Aided Tracking System)***, location system for emergency calls from transmitters at 121.5 or 243 or 406 MHz.

On ***MetOp-3*** HIRS/4 will be dropped, AMSU-A and AVHRR/3 might be replaced by

- ***ATMS (Advanced Technology Microwave Sounder)***, the successor of AMSU-A and AMSU-B for nearly-all-weather temperature and humidity sounding; 22-channel MW radiometer with bands at 54 and 183 GHz, resolution 16 km at 183 GHz and 32 km at 54 GHz, swath 2200 km. See the instrument sheet in Appendix.
- ***VIRI-M (Visible Infra red Imager for MetOp)***: 11-channel VIS/IR radiometer for multi-purpose imagery with 1.1 km resolution and 2900 km swath. See the instrument sheet in Appendix.

Data transmission from MetOp/EPS

The full information from all instruments is stored on board and transmitted in X-band as:

- ***GDS (Global Data Stream)***: frequency 7800 MHz, bandwidth 63 MHz, data rate 70 Mbps.

Direct read-out is provided according to two systems, both digital:

- ***AHRPT (Advanced High Resolution Picture Transmission)***, for the whole information at full resolution in digital form at S-band frequencies. Main features:
  - frequencies: 1701.3 MHz; bandwidth: 4.5 MHz; polarisation: right-hand circular (backup: 1707 MHz, polarisation right-hand circular)
  - antenna diameter ~ 2 m, G/T ~ 6.0 dB/K, data rate 3.5 Mbps;
- ***LRPT (Low Resolution Picture Transmission)***, for selected information (3 AVHRR channel JPEG-compressed and ATOVS data) in digital form at VHF frequencies. Main features:
  - frequency: 137.9 MHz; bandwidth: 150 kHz; polarisation: right-hand circular (backup: 1707 MHz, polarisation right-hand circular)
  - Yagi antenna, G/T ~ -22.4 dB/K, data rate 72 kbps.

2.6 The Meteor programme

The Russian ***Meteor*** programme, if considered inclusive of the experiments carried out on the multi-purpose ***Cosmos*** series, has origins nearly long-standing as those of the American TIROS-ESSA-ITOS-NOAA-POES. However, the first satellite dedicated to operational meteorology is dated 1969. There have been three series, Meteor-1, Meteor-2 and Meteor-3, in non-sunsynchronous orbits whereas the current one, Meteor-3M, is sunsynchronous. The programme run through the following phase.

- ***Meteor-1***, 25 flight models launched, 3-axis stabilised. Instruments:
  - TV camera (0.4-0.8 µm), resolution 1.25-3 km, swath 1000 km
  - IR radiometer (8-12 µm), resolution 15 km, swath 1000 km
  - AC, radiometer for Earth radiation budget (0.3-30 µm), resolution 45 km, swath 2500 km.
- ***Meteor-2***, 21 flight models launched, 3-axis stabilised. Instruments:
  - TV camera (0.4-0.8 µm), resolution 1.25-3 km, swath 1000 km
  - IR radiometer (8-12 µm), resolution 15 km, swath 1000 km
  - SM, IR temperature and humidity sounder (see next)
  - RMK-2, *in situ* charged particles counters (see next).
- ***Meteor-3***, 7 flight models launched, 3-axis stabilised. Instruments:
  - MR-2000M and MR-900B, two cameras (0.5-0.8 µm), one with resolution 1 km and swath 3100 km, the other with resolution 1.5 km and swath 2600 km;
  - Klimat, an IR radiometer (10.5-12.5 µm) with resolution 3 km and swath 3100 km;
  - SM, a 10-channel IR radiometer in the range 9.65-18.70 µm for temperature and humidity sounding; resolution 42 km, swath 1000 km;
  - RMK-2, a suite of charged particle counters to in situ observe solar wind;
  - TOMS (Total Ozone Mapping Spectrometer) (only on Meteor-3-6), a NASA-provided six-bands UV spectrometer (0.31-0.38 µm) with resolution 47 km and swath 3100 km;
  - ScaRaB (Scanner for Radiation Budget) (only on Meteor-3-7) a CNES-provided radiometer with two broad-band (0.2-4.0 µm and 0.2-50 µm) and two narrow-band (0.5-0.7 µm and 10.5-12.5 µm) channels; resolution 60 km, swath 3200 km.

The current series, ***Meteor-3M***, is based on a 3-axis stabilised platform in a sunsynchronous orbit (see ***Fig. 3.6.1***). The first flight model, Meteor-3M N1, currently operational, was launched in December 2001. A second flight model, Meteor-3M N2, is being developed and will be followed by N3. ***Table 3.6.1*** records the chronology of the Meteor programme.

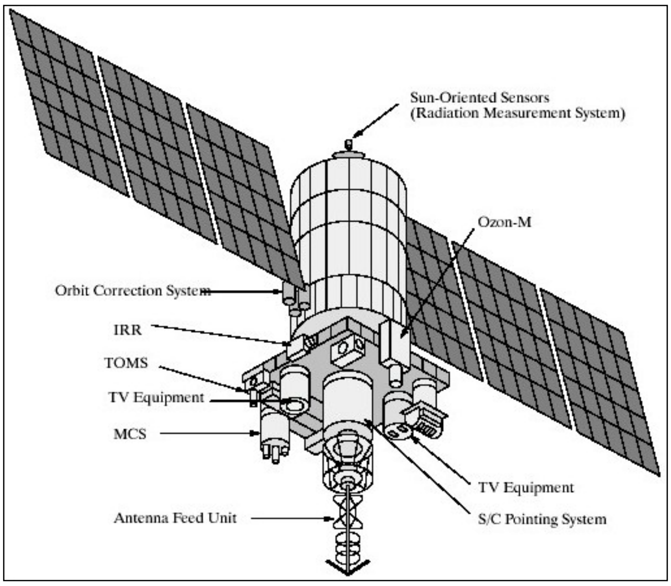


Fig. 3.6.1 – Sketch view of Meteor-3.

Table 3.6.1 – Chronology of the Meteor programme *(in bolt the satellites active at end 2003)*

Satellite	Launch	End of service	Height	LST or inclin.	Status (Dec 2003)	Instruments
Meteor-1-1	23 Mar 1969	~ 1970	680 km	81.2°	Inactive	TV, IR, AC
Meteor-1-2	6 Oct 1969	~ 1970	660 km	81.2°	Inactive	TV, IR, AC
Meteor-1-3	17 Mar 1970	~ 1971	650 km	81.2°	Inactive	TV, IR, AC
Meteor-1-4	28 Apr 1970	~ 1971	680 km	81.2°	Inactive	TV, IR, AC
Meteor-1-5	23 Jun 1970	~ 1971	880 km	81.2°	Inactive	TV, IR, AC
Meteor-1-6	15 Oct 1970	~ 1971	650 km	81.2°	Inactive	TV, IR, AC
Meteor-1-7	20 Jan 1971	~ 1972	650 km	81.2°	Inactive	TV, IR, AC
Meteor-1-8	17 Apr 1971	~ 1972	630 km	81.2°	Inactive	TV, IR, AC
Meteor-1-9	6 Jul 1971	~ 1972	630 km	81.2°	Inactive	TV, IR, AC
Meteor-1-10	29 Dec 1971	~ 1972	890 km	81.2°	Inactive	TV, IR, AC
Meteor-1-11	30 Mar 1972	~ 1973	890 km	81.2°	Inactive	TV, IR, AC
Meteor-1-12	30 Jun 1972	~ 1973	910 km	81.2°	Inactive	TV, IR, AC
Meteor-1-13	27 Oct 1972	~ 1973	900 km	81.2°	Inactive	TV, IR, AC
Meteor-1-14	20 Mar 1973	~ 1974	890 km	81.2°	Inactive	TV, IR, AC
Meteor-1-15	29 May 1973	~ 1974	890 km	81.2°	Inactive	TV, IR, AC
Meteor-1-16	5 Mar 1974	~ 1975	880 km	81.2°	Inactive	TV, IR, AC
Meteor-1-17	24 Apr 1974	~ 1975	890 km	81.2°	Inactive	TV, IR, AC
Meteor-1-19	28 Oct 1974	~ 1975	890 km	81.2°	Inactive	TV, IR, AC
Meteor-1-20	17 Dec 1974	~ 1975	890 km	81.2°	Inactive	TV, IR, AC
Meteor-1-21	1 Apr 1975	~ 1976	890 km	81.2°	Inactive	TV, IR, AC
Meteor-2-1	11 Jul 1975	~ 1976	890 km	81.3°	Inactive	TV, IR, SM, RMK-2
Meteor-1-22	18 Sep 1975	~ 1976	890 km	81.2°	Inactive	TV, IR, AC
Meteor-1-23	25 Dec 1975	~ 1976	880 km	81.2°	Inactive	TV, IR, AC
Meteor-1-24	7 Apr 1976	~ 1977	880 km	81.2°	Inactive	TV, IR, AC
Meteor-1-26	5 Oct 1976	~ 1977	890 km	81.2°	Inactive	TV, IR, AC
Meteor-2-2	6 Jan 1977	~ 1978	910 km	81.3°	Inactive	TV, IR, SM, RMK-2
Meteor-1-28	5 Apr 1977	~ 1978	890 km	81.2°	Inactive	TV, IR, AC
Meteor-2-3	14 Dec 1977	~ 1979	890 km	81.2°	Inactive	TV, IR, SM, RMK-2
Meteor-2-4	1 Mar 1979	~ 1980	880 km	81.2°	Inactive	TV, IR, SM, RMK-2
Meteor-2-5	31 Oct 1979	~ 1980	890 km	81.2°	Inactive	TV, IR, SM, RMK-2
Meteor-2-6	9 Sep 1980	~ 1981	890 km	81.2°	Inactive	TV, IR, SM, RMK-2
Meteor-2-7	15 May 1981	~ 1982	890 km	81.3°	Inactive	TV, IR, SM, RMK-2
Meteor-2-8	25 Mar 1982	~ 1983	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-2-9	15 Dec 1982	~ 1984	870 km	81.3°	Inactive	TV, IR, SM, RMK-2
Meteor-2-10	28 Oct 1983	~ 1985	840 km	81.2°	Inactive	TV, IR, SM, RMK-2
Meteor-2-11	5 Jul 1984	~ 1985	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-2-12	7 Feb 1985	~ 1986	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-3-1	24 Oct 1985	~ 1987	1250 km	82.5°	Inactive	MR-2000M, MR-900B, Klimat, SM,RMK-2
Meteor-2-13	6 Dec 1985	~ 1987	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-2-14	27 May 1986	~ 1987	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-2-15	5 Jan 1987	~ 1988	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-2-16	18 Aug 1987	~ 1988	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-2-17	30 Dec 1987	~ 1989	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-2-18	30 Jan 1988	~ 1989	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-3-3	26 Jul 1988	~ 1990	1210 km	82.5°	Inactive	MR-2000M, MR-900B, Klimat, SM,RMK-2
Meteor-2-19	28 Feb 1989	~ 1990	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-3-4	25 Oct 1989	~ 1992	1210 km	82.5°	Inactive	MR-2000M, MR-900B, Klimat, SM,RMK-2
Meteor-2-20	28 Jun 1990	~ 1992	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-2-21	28 Sep 1990	~ 2001	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-3-5	24 Apr 1991	2003	1210 km	82.5°	Inactive	MR-2000M, MR-900B, Klimat, SM,RMK-2
Meteor-3-6	15 Aug 1991	~ 1993	1210 km	82.5°	Inactive	MR-2000M, MR-900B, Klimat, SM,RMK-2, TOMS
Meteor-2-22	31 Aug 1993	1994	960 km	82.5°	Inactive	TV, IR, SM, RMK-2
Meteor-3-7	25 Jan 1994	1995	1200 km	82.5°	Inactive	MR-2000M, MR-900B, Klimat, SM, ScaRaB
Meteor-3M-N1	**10 Dec 2001**	**expected ≥ 2005**	**830 km**	**9.15**	**Operational**	**MR-2000M1, Klimat, MIVZA, MTVZA, MSU-E, SAGE-III, SFM-2, KGI-4C, MSGI-5EI**
Meteor-3M-N2	2005	expected ≥ 2009	830 km	9.15	Buing built	MSU-MR, IRFS-2, MTVZA, KMSS, Radiomet, Severjanin, GGAK-M
Meteor-3M-N3	2008	expected ≥ 2012	830 km	9.15	Planned	MSU-MR, IRFS-2, MTVZA, KMSS, Radiomet, Severjanin, GGAK-M

Payload of the current satellite, Meteor-3M N1

- ***MR-2000M1***, TV camera (0.5-0.8 µm), resolution 1 km, swath 3100 km. See the instrument sheet in Appendix.
- ***Klimat***, IR radiometer (10.5-12.5 µm), resolution 3.0 km, swath 3100 km. See the instrument sheet in Appendix.
- ***MIVZA***, 3-frequencies / 5 channels (double polarisation at two frequencies) MW conical-scanning radiometer, resolution ..... km at 94 GHz, ... km at 20 GHz, swath 1500 km. See the instrument sheet in Appendix.
- ***MTVZA***, MW sounding-imaging radiometer. See next, under Meteor-3M-N2.
- ***MSU-E***, 3-channels VIS/NIR radiometer (0.5-0.6, 0.6-0.7, 0.8-0.9 µm) for high-resolution (38 m) limited swath imagery (46 km with possible pointing within 430 km).
- ***SAGE-III (Stratospheric Aerosol and Gas Experiment – III)***, a NASA-provided grating spectrometer in 9 bands of the 290-1550 nm range for high-vertical-resolution atmospheric sounding (1-2 km) during solar or lunar occultation. See the instrument sheet in Appendix.
- ***SFM-2***, a UV spectrometer for ozone during solar occultation. Spectral range .... nm, vertical resolution 1-2 km. See the instrument sheet in Appendix.
- ***KGI-4C*** and ***MSGI-5EI***, suite of charged particles counters for *in situ* observation of solar wind.

On ***Meteor-3M N2*** the payload is being substantially re-designed, as follows.

- ***MSU-MR***, replacing MR-2000M1 + Klimat for multi-purpose imagery: 6-channel VIS/IR radiometer, resolution 1.0 km, swath 3000 km. See the instrument sheet in Appendix.
- ***IRFS***-2, IR interferometer for high-vertical-resolution temperature/humidity sounding, about 4000 channels with spectral resolution 0.3 cm^{-1}, resolution 35 km, swath 2000 km. See the instrument sheet in Appendix.
- ***MTVZA***, a 20-frequency / 26-channel radiometer (double polarisation for six frequencies), with 6 more channels than on Meteor-3M-N1, for multi-purpose MW imagery and nearly-all-weather temperature/humidity sounding; conical scanning with resolution between 17 km at 183 GHz and 100 km at 19 GHz, swath 2200 km. See the instrument sheet in Appendix.
- ***KMSS***, replacing MSU-E by adding one channel (0.4-0.5 µm) and degrading the resolution to 100 m in favour of larger swath.
- ***Radiomet***, for all-weather very-high-vertical resolution temperature and humidity profile by observing the phase delay of GPS signals received during the occultation phase. 0.5-1 km vertical resolution, ~ 300 km horizontal resolution; 500 measurements/day. See the instrument sheet in Appendix.
- ***Severjanin***, a Synthetic Aperture Radar (SAR): X-band (9500-9700 GHz), resolution either 450 or 900 m, swath 450 km.
- ***GGAK-M***, replacing KGI-4C + MSGI-5EI for *in situ* observation of charged particles in solar wind.

Data transmission from Meteor-3M

Global data are stored on board and transmitted in X-band to:

- Command and Data Acquisition station (CDA): frequency 8192 MHz, bandwidth 32 MHz, data rate 15.36 Mbps.

As for direct read-out, Meteor-3M N1 has lost the APT transmission capability and can provide a HRPT-like transmission at 1700 GHz, by with data in non-HRPT-compatible format. Meteor-3M N2 will comply with standards similar to NOAA:

- ***HRPT (Advanced High Resolution Picture Transmission)***, for the whole information at full resolution in digital form at S-band frequencies. Main features:
  - frequencies: 1700 MHz; bandwidth: 2.0 MHz; polarisation: right-hand circular
  - antenna diameter ~ 2 m, G/T ~ 6.0 dB/K, data rate 665 kbps.
- ***LRPT (Low Resolution Picture Transmission)***, for selected information. Main features:
  - frequency: 137.89 or 137.1 MHz; bandwidth: 150 kHz; polarisation: right-hand circular
  - Yagi antenna, G/T ~ -22.4 dB/K, data rate 64 kbps.

2.7 The FY-1 and FY-3 programmes

The Chinese ***FY-1*** and ***FY-3*** series started in 1988. The first two satellites (FY-1A and FY-1/B) were using the ITOS platform (see section 3.2 and Fig. 3.2.3), the next two (FY-1C and FY-1D) a new platform (***Fig. 3.7.1***). The FY-3 series is being developed and include 7 flight models. All satellites are 3-axis stabilised, in sunsynchronous orbit. ***Table 3.7.1*** records the chronology of the FY-1 / FY-3 programme.

Table 3.7.1 – Chronology of the FY-1/FY-3 programme *(in bolt the satellites active at end 2003)*

Satellite	Launch	End of service	Height	LST	Status (Dec 2003)	Instruments
FY-1A	7 Sep 1988	16 Oct 1988	900 km	11.30	Inactive	MVISR, SEM
FY-1B	3 Sep 1990	5 Aug 1991	900 km	16.00	Inactive	MVISR, SEM
FY-1C	**10 May 1999**	**expected ≥ 2004**	**862 km**	**6.45**	**Operational**	**MVISR, SEM**
FY-1D	**15 May 2002**	**expected ≥ 2006**	**866 km**	**8.30**	**Operational**	**MVISR, SEM**
FY-3A	2006	expected ≥ 2009	866 km	10.00	Buing built	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, SEM
FY-3B	2008	expected ≥ 2011	866 km	10.00	Buing built	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, SEM
FY-3C	2010	expected ≥ 2013	866 km	10.00	Planned	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, SEM
FY-3D	2012	expected ≥ 2015	866 km	10.00	Planned	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, SEM
FY-3E	2014	expected ≥ 2017	866 km	10.00	Planned	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, SEM
FY-3F	2016	expected ≥ 2019	866 km	10.00	Planned	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, SEM
FY-3G	2018	expected ≥ 2021	866 km	10.00	Planned	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, SEM

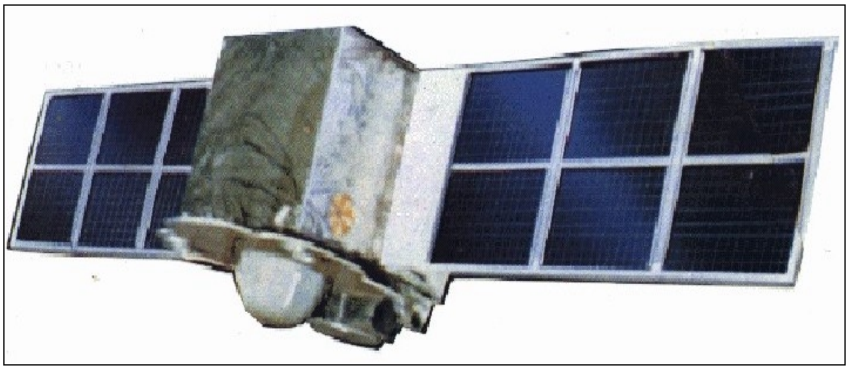


Fig. 3.7.1 – View of FY-1.

Payload of FY-1

At end 2003, the operational satellites are ***FY-1C***, launched in 1999, and ***FY-1D***, launched in 2002. They embark a single instrument:

- ***MVISR (Multichannel Visible and Infrared Scanning Radiometer)***, VIS/IR radiometer for multi-purpose imagery, resolution 1.1 km, swath 2800 km. On FY-1A and FY-1B MVISR had 5 channels (0.48-0.53, 0.53-0.58, 0.58-0.68, 0.725-1.10 e 10.5-12.5 µm). On FY-1C and FY-1D there are 10 channels. See the instrument sheet in Appendix.
- ***SEM (Space Environment Monitoring)*** for *in situ* observation of charged particles in solar wind.

Data transmission from FY-1

Global data are stored on board and transmitted in S-band as:

- China Delayed Picture Transmission (CDPT): MVISR imagery with resolution reduced to 4 km; frequency 1708.5 MHz (backup 1695.5 MHz, bandwidth 5.6 MHz, data rate 1.33 Mbps.

As for direct read-out, there is:

- ***CHRPT (China High Resolution Picture Transmission)***, for the whole information at full resolution in digital form at S-band frequencies. Main features:
  - frequencies: 1700.5 MHz (backup 1704.5 GHz); bandwidth: 5.6 MHz; polarisation: right-hand circular
  - antenna diameter ~ 2 m, G/T ~ 6.0 dB/K, data rate 1.33 kbps.

Payload of FY-3

- ***VIRR (Visible and Infra Red Radiometer)***, close to MVISR except that the water vapour channel at 932 nm is replaced by 1360 nm; 10-channel VIS/IR radiometer for multi-purpose imagery, resolution 1.1 km, swath 2800 km. See the instrument sheet in Appendix.
- ***MERSI (Medium Resolution Spectral Imager)***, 20-channel radiometer (19 in VIS/NIR/SWIR + one TIR at 10.0-12.5 µm) for ocean colour and vegetation indexes; resolution 250 m for 4 VIS/NIR and the TIR channel, 1 km for all other channels; swath ...... km. See the instrument sheet in Appendix.
- ***MWRI (Micro-Wave Radiation Imager)***, 6-frequencies / 12 channels (all frequencies in double polarisation) for multi-purpose MW imagery. Conical-scanning radiometer, resolution ..... km at 90 GHz, ... km at 19 GHz, swath 1400 km. See the instrument sheet in Appendix.
- ***IRAS (Infra Red Atmospheric Sounder)***, 26-channel IR radiometer (including one VIS) for temperature/humidity sounding, resolution 17 km, swath 2250 km. See the instrument sheet in Appendix.
- ***MWTS (Micro-Wave Temperature Sounder)***, 4-channel MW radiometer for nearly-all-weather temperature sounding, 54 GHz band, resolution 70 km, cross-track scanning, swath ...... km. See the instrument sheet in Appendix.
- ***MWHS (Micro-Wave Humidity Sounder)***, 4-frequency / 5-channel (one frequency in double polarisation) MW radiometer for nearly-all-weather humidity sounding, 118 GHz band, resolution 15 km, cross-track scanning, swath ...... km. See the instrument sheet in Appendix.
- ***TOU/SBUS (Total Ozone Unit and Solar Backscatter Ultraviolet Sounder)***, 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 252-380 nm, resolution 200 km, nadir viewing, for ozone profile. See the instrument sheet in Appendix.
- ***SEM (Space Environment Monitoring)*** for *in situ* observation of charged particles in solar wind.

Data transmission from FY-3

The data rate of the MERSI instrument requires moving to X-band, both for global data recovery and for full information real-time transmission. Global data stored on board are transmitted as:

- Delayed Picture Transmission (DPT): frequency in the range 8025-8215 MHz or 8215-8400 MHz, bandwidth 120 MHz, data rate 93 Mbps.

Direct read-out is provided according to two systems:

- ***MPT (............... Picture Transmission)***, for full information in X-band. Main features:
  - frequency: in the range 7750-7850 MHz; bandwidth: 35 MHz; polarisation: right hand circular
  - antenna diameter ~ .... m, G/T ~ .... dB/K, data rate 18.2 Mbps;
- ***AHRPT (Advanced High Resolution Picture Transmission)*** for selected information in S-band. Main features:
  - frequency: in the range 1698-1710 MHz; bandwidth: 5.6 MHz; polarisation: right hand circular
  - antenna diameter ~ .... m, G/T ~ .... dB/K, data rate 4.2 Mbps.

2.8 Coverage provided by sunsynchronous satellites at end-2003 and in year 2006

In this section the compliance of the constellation of sunsynchronous meteorological satellites with WMO requirements is evaluated. Since the requirement calls for four satellites at optimally-spaced LST, ***Table 3.8.1*** identifies eight time sectors each wide 3 hours. However, since the current situation is rather unstable (several satellites are end-of-life), and waiting for MetOp/EPS, Meteor-3M-N2, FY-3, it is useful to also consider the perspective situation in year 2006 according to known plans. This is shown in ***Table 3.8.2***.

Table 3.8.1 - Coverage from sunsynchronous satellites as of end 2003 (CGMS XXXI)

Time	Satellite	LST	Instruments
00-03	NOAA-16	02.15 d	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2,SEM/2, Argos, SARSAT
03-06			
06-09	DMSP F13	06.25 d	SSM/I, SSM/T + others not available
	NOAA-15	06.30 d	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SEM/2, Argos, SARSAT
	FY-1C	06.45 d	MVISR, SEM
	FY-1D	08.30 d	MVISR, SEM
	DMSP F14	07.40 d	SSM/I, SSM/T, SSM/T-2 + others not available
09-12	Meteor-3M-N1	09.15 d	MR-2000M1, Klimat, MIVZA, MTVZA, MSU-E, SAGE-III, SFM-2, KGI-4C, MSGI-5EI
	DMSP F15	09.15 d	SSM/I, SSM/T, SSM/T-2 + others not available
	NOAA-17	10.20 d	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2,SEM/2, Argos, SARSAT
12-15	NOAA-16	14.15 a	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2,SEM/2, Argos, SARSAT
15-18			
18-21	DMSP F13	18.25 a	SSM/I, SSM/T + others not available
	NOAA-15	18.30 a	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SEM/2, Argos, SARSAT
	FY-1C	18.45 a	MVISR, SEM
	DMSP F14	19.40 a	SSM/I, SSM/T, SSM/T-2 + others not available
	FY-1D	20.30 a	MVISR, SEM
21-24	Meteor-3M-N1	21.15 a	MR-2000M1, Klimat, MIVZA, MTVZA, MSU-E, SAGE-III, SFM-2, KGI-4C, MSGI-5EI
	DMSP F15	21.15 a	SSM/I, SSM/T, SSM/T-2 + others not available
	NOAA-17	22.20 a	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2,SEM/2, Argos, SARSAT

Table 3.8.2 - Coverage from sunsynchronous satellites as expected in 2006 (CGMS XXXI)

Time	Satellite	LST	Instruments
00-03	NOAA-18	02.00 d	AVHRR/3, HIRS/3, AMSU-A, MHS, SBUV/2,SEM/2, Argos, SARSAT
03-06	DMSP F17	05.30 d	SSMIS
06-09	DMSP F16	08.00 d	SSMIS
	FY-1D	08.30 d	MVISR, SEM
09-12	Meteor-3M-N2	09.15 d	MSU-MR, IRFS-2, MTVZA, KMSS, Radiomet, Severjanin, GGAK-M
	MetOp-1	09.30 d	AVHRR/3, HIRS/4, AMSU-A, MHS, IASI, GOME-2, GRAS, ASCAT, SEM/2, Argos, SARSAT
	FY-3A	10.00 d	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, SEM
	NOAA-17	10.20 d	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2,SEM/2, Argos, SARSAT
	NPP	10.30 d	VIIRS, CrIS, ATMS, OMPS
12-15	NOAA-18	14.00 a	AVHRR/3, HIRS/3, AMSU-A, MHS, SBUV/2,SEM/2, Argos, SARSAT
15-18	DMSP F17	17.30 a	SSMIS
18-21	DMSP F16	20.00 a	SSMIS
	FY-1D	20.30 a	MVISR, SEM
21-24	Meteor-3M-N2	21.15 a	MSU-MR, IRFS-2, MTVZA, KMSS, Radiomet, Severjanin, GGAK-M
	MetOp-1	21.30 a	AVHRR/3, HIRS/4, AMSU-A, MHS, IASI, GOME-2, GRAS, ASCAT, SEM/2, Argos, SARSAT
	FY-3A	22.00 a	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, SEM
	NOAA-17	22.20 a	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2,SEM/2, Argos, SARSAT
	NPP	22.30 a	VIIRS, CrIS, ATMS, OMPS

Fig. 3.8.1, ***Fig. 3.8.2*** and ***Fig. 3.8.3*** show the 3-hourly coverage as current (at end-2003) and expected (in 2006) for the VIS/IR imagery mission, the IR/MW sounding mission and MW conical scanners respectively. These figures should be compared to Fig. 1.2 showing the WMO requirement.

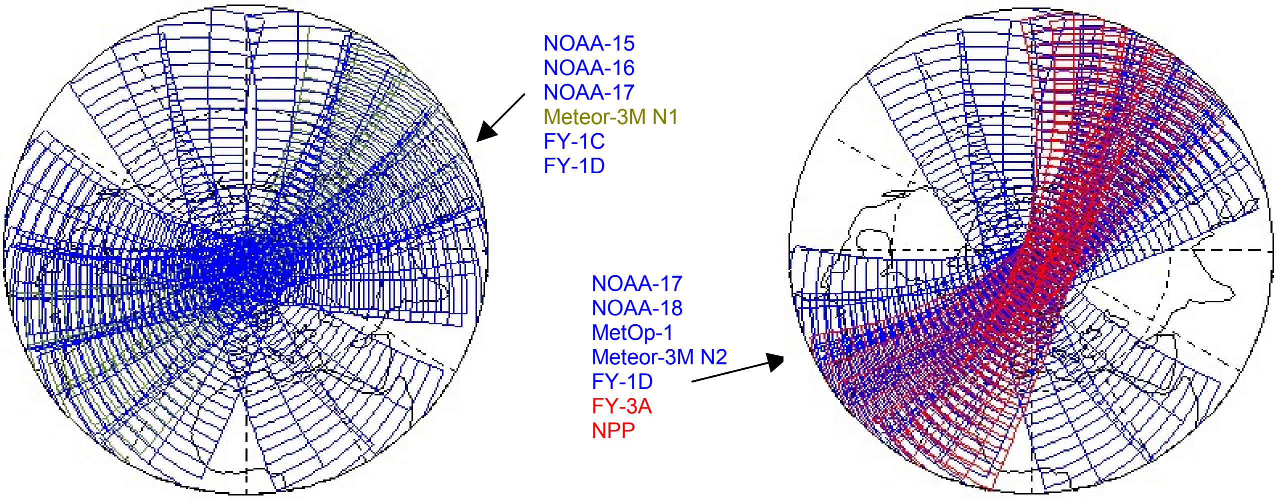


Fig. 3.8.1 – 3-hourly coverage for the VIS/IR imagery mission. Left: end-2003. Right: 2006. Green: MSR-2000M1 + Klimat. Blue: AVHRR, MVISR, MSU-MR. Red: MERSI+VIRR, VIIRS.

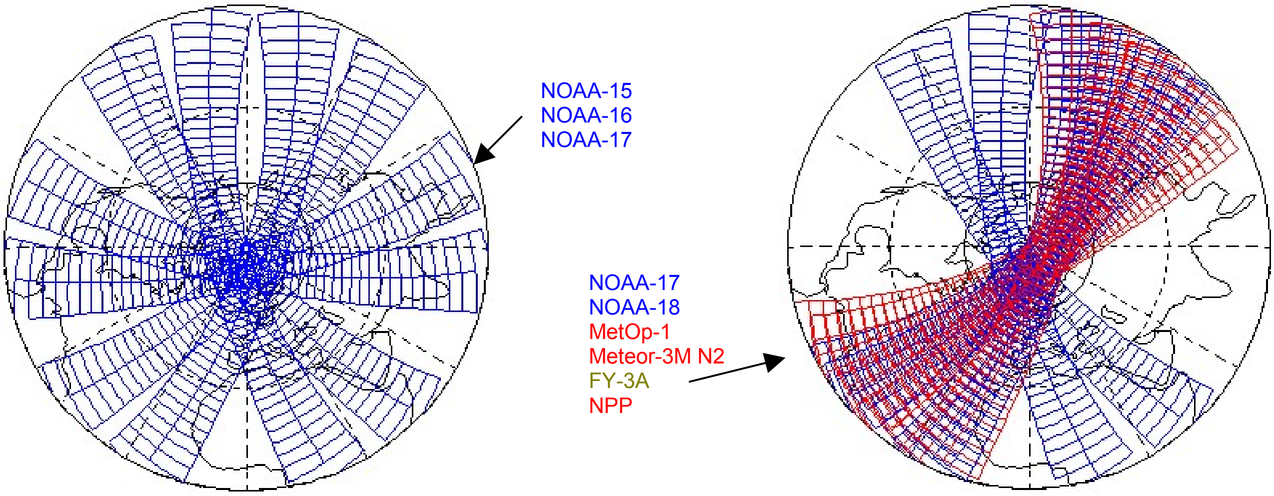


Fig. 3.8.2 – 3-hourly coverage for the IR/MW sounding mission. Left: end-2003. Right: 2006. Green: IRAS+MWTS+MWHS. Blue: ATOVS. Red: ATOVS+IASI, IRFS-2+MTVZA, CrIS+ATMS.

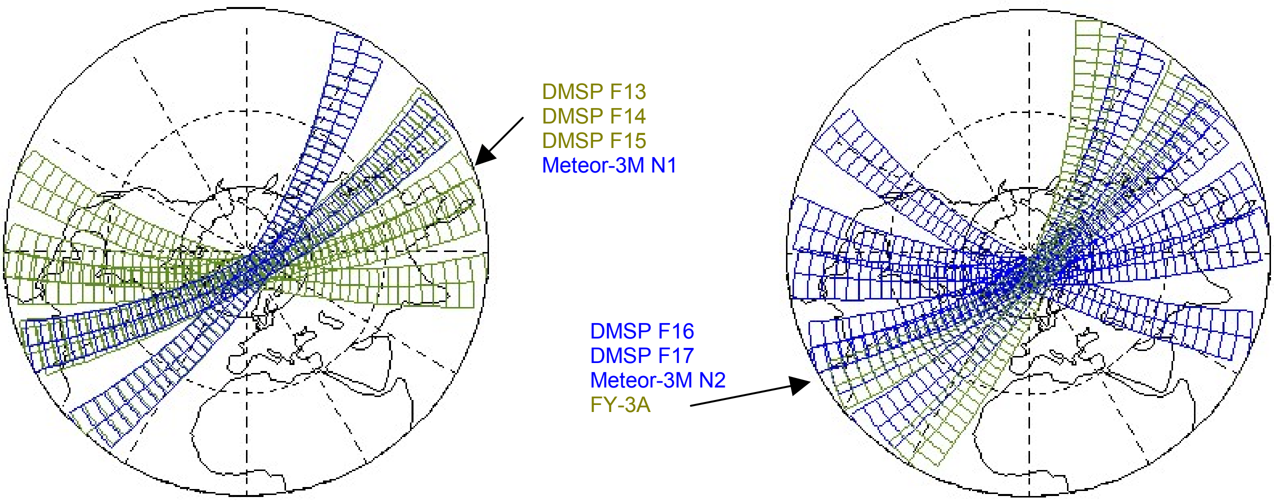


Fig. 3.8.3 – 3-hourly coverage for MW conical scanners. Left: end-2003. Right: 2006. Green: SSM/I, MWRI. Blue: imaging-sounders: SSMIS, MTVZA. Red: reserved for CMIS (2009).

Table 3.8.3, ***Table 3.8.4*** and ***Table 3.8.5*** highlight the situation of orbital parameters in respect of the VIS/IR imagery mission, the IR/MW sounding mission and for MW conical scanners, respectively. The role of these Tables is to identify the time of the day when gaps occur because of the orbital configuration of the constellation. The ***gaps***, instead, arise from the combined effect of the orbital configuration and the instrument swaths (limited to ~ 2200 km for sounders and ~ 1400 km for MW conical scanners), and can be appreciated from Fig. 3.8.1, Fig. 3.8.2 and Fig. 3.8.3.

Table 3.8.3 – Coverage of the VIS/IR imagery mission *(cells with ΔLST > 3 h are highlighted)*

2003	NOAA-16	NOAA-15	FY-1C	FY-1D	Meteor-3M-N1	NOAA-17	NOAA-16	NOAA-15	FY-1C	FY-1D	Meteor-3M-N1	NOAA-17	NOAA-16
LST	02.15	06.30	06.45	08.30	09.15	10.20	14.15	18.30	18.45	20.30	21.15	22.20	02.15
ΔLST		4 h 15’	0 h 15’	1 h 45’	0 h 45’	1 h 05’	3 h 55’	4 h 15’	0 h 15’	1 h 45’	0 h 45’	1 h 05’	3 h 55’

2006	NOAA-18	FY-1D	Meteor-3M-N2	MetOp-1	FY-3A	NOAA-17	NPP	NOAA-18	FY-1D	Meteor-3M-N2	MetOp-1	FY-3A	NOAA-17	NPP	NOAA-18
LST	02.00	08.30	09.15	09.30	10.00	10.20	10.30	14.00	20.30	21.15	21.30	22.00	22.20	22.30	02.00
ΔLST		6 h 30’	0 h 45’	0 h 15’	0 h 30’	0 h 20’	0 h 10’	3 h 30’	6 h 30’	0 h 45’	0 h 15’	0 h 30’	0 h 20’	0 h 10’	3 h 30’

Analysis of Table 3.8.3

- ***2003*** – lack of satellite availability (actual ΔLST ~ 4 hours) four times/day, around LST’s 00.30, 04.30, 12.30 and 16.30;
- ***2006 –*** severe lack of satellite availability (actual ΔLST ~ 6 h 30’) in early morning (~ 05.00) and late-afternoon (~ 17.00); minor gaps (ΔLST ~ 3 h 30’) around noon and midnight.

Table 3.8.4 – Coverage of the IR/MW sounding mission *(cells with ΔLST > 3 h are highlighted)*

2003	NOAA-16	NOAA-15	NOAA-17	NOAA-16	NOAA-15	NOAA-17	NOAA-16
LST	02.15	06.30	10.20	14.15	18.30	22.20	02.15
ΔLST		4 h 15’	3 h 50’	3 h 55’	4 h 15’	3 h 50’	3 h 55’

2006	NOAA-18	Meteor-3M-N2	MetOp-1	FY-3A	NOAA-17	NPP	NOAA-18	Meteor-3M-N2	MetOp-1	FY-3A	NOAA-17	NPP	NOAA-18
LST	02.00	09.15	09.30	10.00	10.20	10.30	14.00	21.15	21.30	22.00	22.20	22.30	02.00
ΔLST		7 h 15’	0 h 15’	0 h 30’	0 h 20’	0 h 10’	3 h 30’	7 h 15’	0 h 15’	0 h 30’	0 h 20’	0 h 10’	3 h 30’

Analysis of Table 3.8.4

- ***2003*** – the 3-hourly requirement cannot be met with three satellites. However, the observing cycle is fairly regular (actual ΔLST ~ 4 hours);
- ***2006 –*** severe lack of satellite availability (actual ΔLST ~ 7 h 15’) in early morning (~ 05.30) and late-afternoon (~ 17.30); minor gaps (ΔLST ~ 3 h 30’) around noon and midnight.

Table 3.8.5 – Coverage of MW conical scanners *(cells with ΔLST > 3 h are highlighted)*

2003	DMSP F13	DMSP F14	Meteor-3M-N1	DMSP F15	DMSP F13	DMSP F14	Meteor-3M-N1	DMSP F15	DMSP F13
LST	06.25	07.40	09.15	09.15	18.25	19.40	21.15	21.15	06.25
ΔLST		1 h 15’	1 h 35’	0 h 00’	9 h 10’	1 h 15’	1 h 35’	0 h 00’	9 h 10’

2006	DMSP F17	DMSP F16	Meteor-3M-N2	FY-3A	DMSP F17	DMSP F16	Meteor-3M-N2	FY-3A	DMSP F17
LST	05.30	08.00	09.15	10.00	17.30	20.00	21.15	22.00	05.30
ΔLST		2 h 30’	1 h 15’	0 h 45’	7 h 30’	2 h 30’	1 h 15’	0 h 45’	7 h 30’

Analysis of Table 3.8.5

- ***2003*** – severe lack of satellite availability (actual ΔLST ~ 9 h 10’) in early afternoon (~ 13.30) and in night (~ 01.30);
- ***2006 –*** severe lack of satellite availability (actual ΔLST ~ 7 h 30’) in early afternoon (~ 13.30) and in night (~ 01.30).

2.9 Comparative instrument performances

In addition to the coverage, the system also must provide homogeneous performances in terms of data quality, that depends on the instruments. ***Table 3.9.1*** compares the main features of imagers being operational at end-2003 and/or in 2006.

Table 3.9.1 – Comparative performances of imagers on-board sun-synchronous satellites

NOAA & MetOp AVHRR/3		**NPP VIIRS**		**Meteor-3M-N1 MR-2000M1 + Klimat**		**Meteor-3M-N2 MSU- MR**		**FY-1C/D & FY-3A MVISR & VIRR**		**FY-3A MERSI**	
λ	**Δλ**	**λ**	**Δλ**	**λ**	**Δλ**	**λ**	**Δλ**	**λ**	**Δλ**	**λ**	**Δλ**
		412 nm	20 nm							412 nm	20 nm
		445 nm	18 nm					455 nm	50 nm	443 nm	20 nm
										470 nm *	50 nm
		488 nm	20 nm					505 nm	50 nm	490 nm	20 nm
										520 nm	20 nm
		555 nm	20 nm					555 nm	50 nm	550 nm *	50 nm
										565 nm	20 nm
				↓ MR-20	00-M1 ↓					650 nm	20 nm
630 nm	100 nm	640 nm *	80 nm	650 nm	200 nm	600 nm	200 nm	630 nm	100 nm	650 nm *	50 nm
		672 nm	20 nm							685 nm	20 nm
		700 nm *	400 nm								
		746 nm	15 nm							765 nm	20 nm
		865 nm	39 nm							865 nm	20 nm
862 nm	275 nm	865 nm *	39 nm					865 nm	50 nm	865 nm *	50 nm
								↓ FY-1/D	MVISR ↓	905 nm	20 nm
						950 nm	300 nm	932 nm	65 nm	940 nm	20 nm
										980 nm	20 nm
		1240 nm	20 nm					↓ FY-3A	VIRR ↓	1030 nm	20 nm
		1378 nm	15 nm					1360 nm	70 nm		
		1610 nm	60 nm								
1610 nm	60 nm	1610 nm *	60 nm			1700 nm	200 nm	1600 nm	90 nm	1640 nm	50 nm
		2250 nm	50 nm							2130 nm	50 nm
		3.70 μm	0.18 μm								
3.74 μm	0.38 μm	3.74 μm *	0.38 μm			3.80 μm	0.6 μm	3.74 μm	0.4 μm		
		4.05 μm	0.16 μm								
		8.55 μm	0.30 μm								
10.80 μm	1.00 μm	10.76 μm	1.00 μm	↓ Klimat	↓	11.00 μm	1.00 μm	10.80 μm	1.00 μm		
		11.45 μm *	1.90 μm	11.5 μm	2.0 μm					11.25 μm *	2.50 μm
12.00 μm	1.00 μm	12.01 μm	0.95 μm			12.00 μm	1.00 μm	12.00 μm	1.00 μm		
6 channels		22 channels		2 channels		6 channels		10 channels		20 channels	
Swath: 2900 km		Swath: 3000 km		Swath: 3100 km		Swath: 3000 km		Swath: 2800 km		Swath: .... km	
IFOV: 1.1 km		IFOV: 800 m (* 400 m) ch. 700 nm: day/night		IFOV: VIS 1 km IR 3 km		IFOV: 1.0 km		IFOV: 1.1 km		IFOV: 1.0 km (* 250 m)	

It may be observed that there are three typologies of VIS/IR imagers:

- remaining models of previous series: MR-2000M1 + Klimat on Meteor-3M-N1;
- AVHRR/3 on NOAA and MetOp, MSU-MR on Meteor-3M-N2, MVISR on FY-1C/D;
- advanced imagers: VIIRS on NPP, MERSI+VIRR on FY-3/A.

In Fig. 3.8.1 the coverage from these different classes of instruments is marked by different colours (green: end-of-series instruments; blue: common current technology; red: advanced instruments).

It is observed from Fig. 3.8.1 that, in addition to the problem of the gap of coverage in the early-morning / late afternoon timeframes, there is the uneven distribution of advanced imagers in 2006, since the two satellites concerned, FY-3A and NPP, are in similar orbits (10.00 and 10.30 respectively).

Table 3.9.2 compares the main features of sounders being operational at end-2003 and/or in 2006. The Table collects information on the IR component (radiometer or spectrometer) and the MW component.

Table 3.9.2 – Comparative performances of sounders on-board sun-synchronous satellites

IR sounders				MW cross-track sounders					
NOAA & MetOp HIRS/3 & HIRS/4		FY-3A IRAS		NOAA & MetOp AMSU-A & AMSU-B / MHS		FY-3A MWTS & MWHS		NPP ATMS	
Central λ	Bandwidth	Central λ	Bandwidth	ν (GHz)	Δν (MHz)	ν (GHz)	Δν (MHz)	ν (GHz)	Δν (MHz)
14.95 μm	3 cm^{-1}	14.95 μm	3 cm^{-1}	23.800	270			23.800	270
		14.80 μm	3 cm^{-1}	31.400	180			31.400	180
14.71 μm	10 cm^{-1}	14.71 μm	10 cm^{-1}	50.300	180	50.300	180	50.300	180
14.49 μm	12 cm^{-1}	14.49 μm	12 cm^{-1}					51.760	400
14.22 μm	16 cm^{-1}	14.22 μm	16 cm^{-1}	52.800	400			52.800	400
13.97 μm	16 cm^{-1}	13.97 μm	16 cm^{-1}	53.596±0.115	170	53.596 ±0.115	340	53.596 ±0.115	170
13.64 μm	16 cm^{-1}	13.64 μm	16 cm^{-1}	54.400	400			54.400	400
13.35 μm	16 cm^{-1}	13.35 μm	16 cm^{-1}	54.940	400	54.94	400	54.940	400
12.47 μm	16 cm^{-1}			55.500	330			55.500	330
11.11 μm	35 cm^{-1}	11.11 μm	35 cm^{-1}	f_0 = 57.290344	330	57.290	330	f_0 = 57.290344	330
9.71 μm	25 cm^{-1}	9.71 μm	25 cm^{-1}	$f_0 \pm 0.217$	78			$f_0 \pm 0.217$	78
		8.16 μm	25 cm^{-1}	$f_0 \pm 0.3222 \pm 0.048$	36			$f_0 \pm 0.3222 \pm 0.048$	36
7.33 μm	40 cm^{-1}	7.33 μm	40 cm^{-1}	$f_0 \pm 0.3222 \pm 0.022$	16			$f_0 \pm 0.3222 \pm 0.022$	16
6.52 μm	55 cm^{-1}	6.52 μm	80 cm^{-1}	$f_0 \pm 0.3222 \pm 0.010$	8			$f_0 \pm 0.3222 \pm 0.010$	8
4.57 μm	23 cm^{-1}	4.57 μm	23 cm^{-1}	$f_0 \pm 0.3222 \pm 0.0045$	3			$f_0 \pm 0.3222 \pm 0.0045$	3
4.52 μm	23 cm^{-1}	4.52 μm	23 cm^{-1}	89.000	2000			89.5	5000
4.47 μm	23 cm^{-1}	4.47 μm	23 cm^{-1}	89.0	1000				
4.45 μm	23 cm^{-1}	4.40 μm	23 cm^{-1}	150.0 (*)	1000	150.0	2000	165.5	3000
4.13 μm	28 cm^{-1}	4.20 μm	23 cm^{-1}	157.0 (**)	2800				
4.00 μm	35 cm^{-1}	4.00 μm	35 cm^{-1}	183.31 ± 7.0 (*)	2000	183.31 ± 7.0	2000	183.31 ± 7.0	2000
3.76 μm	100 cm^{-1}	3.76 μm	100 cm^{-1}					183.31 ± 4.5	2000
		1.64 μm	TBD	183.31 ± 3.0	1000	183.31 ± 3.0	1000	183.31 ± 3.0	1000
		1.24 μm	TBD					183.31 ± 1.8	1000
		0.94 μm	TBD	183.31 ± 1.0	500	183.31 ± 1.0	500	183.31 ± 1.0	500
		0.885 μm	TBD	193.31 (**)	2200				
0.69 μm	1000 cm^{-1}	0.69 μm	1000 cm^{-1}						
		0.659 μm	TBD	(*) AMSU-B	(**) MHS				
20 channels		26 channels		15 + 5 channels		4 + 5 channels		22 channels	
Swath: 2250 km		Swath: 2250 km		Swath: 2250 km		Swath: 2250 km		Swath: 2300 km	
IFOV: 18 km (HIRS-3) 10 km /HIRS-4)		IFOV: 17 km		IFOV: 48 km (AMSU-A) 16 km (AMSU-B)		IFOV: 70 km (MWTS) 15 km (MWHS)		IFOV: 32 km (temperature) 16 km (humidity)	

Advanced IR sounders

Parameter	MetOp IASI	NPP CrIS	Meteor-3M-N2 IRFS-2
Spectral range	3.62-15.5 μm (645-2760 cm^{-1})	3.92-15.4 μm (650-2550 cm^{-1})	5-15 μm (665-2000 cm^{-1})
Bands and spectral resolution	8.26-15.50 μm, 0.25 cm^{-1}	9.13-15.40 μm, 0.625 cm^{-1}	0.3 cm^{-1}
	5.00-8.26 μm, 0.25 cm^{-1}	5.71-8.26 μm, 1.25 cm^{-1}	
	3.62-5.00 μm, 0.25 cm^{-1}	3.92-4.64 μm, 2.5 cm^{-1}	
Channels	8460	1302	~ 4000
NEΔT	0.2-0.35 K @ 280 K	0.1-0.5 K @ 250 K	???
IFOV at s.s.p.	12 km	14 km	35 km
Sampling	2 x 2 IFOVs in 48 x 48 km^2	3 x 3 IFOVs in 48 x 48 km^2	1 IFOV in 100 x 100 km^2
Swath	2230 km (30 FOV's/scan)	2230 (30 FOV's/scan)	2000 km (20 FOV's/scan)

It may be observed that there are three typologies of sounding systems, depending on the IR component being a radiometer or a spectrometer, and the MW sounder being of the MSU or the AMSU class:

- TOVS-like: IRAS + MWTS + MWHS on FY-3A;
- ATOVS: HIRS + AMSU-A + AMSU-B/MHS on NOAA and MetOp;
- advanced sounders: ATOVS + IASI on MetOp, CrIS + ATMR on NPP, IRFS-2 + MTVZA on Meteor-3M-N2.

In Fig. 3.8.2 the coverage from these different classes of instruments is marked by different colours (green: TOVS-like; blue: ATOVS; red: advanced instruments).

It is observed from Fig. 3.8.2 that, in addition to the problem of the gap of coverage in the early-morning / late afternoon timeframes, there is the uneven distribution of advanced sounders in 2006, since the three satellites concerned, Meteor-3M-N2, MetOp and NPP, are in similar orbits (09.15, 09.30 and 10.30 respectively).

Table 3.9.3 compares the main features of conical scanning MW radiometers being operational at end-2003 and/or in 2006.

Table 3.9.3 – Comparative performances of MW conical scanners (imagers and imaging/sounders)

FY-3A MWRI			Meteor-3M N1 MIVZA			DMSP SSM/I			DMSP SSMIS			Meteor-3M MTVZA		
ν (GHz)	Δν (MHz)	Pol.	ν (GHz)	Δν (MHz)	Pol.	ν (GHz)	Δν (MHz)	Pol.	ν (GHz)	Δν (MHz)	Pol.	ν (GHz)	Δν (MHz)	Pol.
~ 10	???	V,H												
~ 19	???	V,H				19.35	400	V,H	19.35	400	V,H	18.7	800	V,H
~ 22	???	V,H	20.0	???	???	22.235	400	V	22.235	400	V	22.235	1600	V
												33.0	2000	V,H
~ 37	???	V,H	35.0	???	V,H	37.0	1500	V,H	37.0	1500	V,H	36.5	2000	V,H
												42.0	2000	V,H
									50.3	400	H	48.0	2000	V,H
									52.8	400	H	52.80	400	V
									53.596	400	H	53.30	400	V
									54.4	400	H	53.80	400	V
												54.64	400	V
									55.5	400	H	55.63	400	V
									f_0 = 57.29	350	-	f_0 = 57.29		
									59.4	250	-	$f_0 \pm 0.3222 \pm 0.1$	50	H
									f_1 = 60.792668			$f_0 \pm 0.3222 \pm 0.05$	20	H
									$f_1 \pm 0.357892 \pm 0.050$	120	V+H	$f_0 \pm 0.3222 \pm 0.025$	10	H
									$f_1 \pm 0.357892 \pm 0.016$	32	V+H	$f_0 \pm 0.3222 \pm 0.01$	5	H
									$f_1 \pm 0.357892 \pm 0.006$	12	V+H	$f_0 \pm 0.3222 \pm 0.005$	3	H
									$f_1 \pm 0.357892 \pm 0.002$	6	V+H			
									$f_1 \pm 0.357892$	3	V+H			
									63.283248 ± 0.285271	3	V+H			
~ 90	???	V,H	94 GHz	???	V,H	85.5	3000	V,H	91.655	3000	V,H	91.65	3000	V,H
~150	???	V,H							150	1500	H			
									183.31 ± 6.6	1500	H	183.31 ± 7.0	1500	V
									183.31 ± 3.0	1000	H	183.31 ± 3.0	1000	V
									183.31 ± 1.0	500	H	183.31 ± 1.0	500	V
12 channels			5 channels			7 channels			24 channels			26 channels		
Swath: 1400 km			Swath: 1500 km			Swath: 1400 km			Swath: 1700 km			Swath: 2200 km		
...... km @ ~90 GHz			.... km @ 94 GHz			12.5 km @ 85.5 GHz			12.5 km @ 91.655 GHz			17 km @ 91.65 GHz		

It may be observed that there are two typologies of MW conical scanners:

- imagers in window channels: SSM/I on DMSP, MWRI on FY-3A, MIVZA on Meteor-3M-N1;
- imaging/sounders: SSMIS on DMSP, MTVZA on Meteor-3M (also supportive of the IR sounders).

In Fig. 3.8.3 the coverage from these different classes of instruments is marked by different colours (green: imagers; blue: imaging/sounders; red is reserved for advanced imaging/sounders, i.e. CMIS). In addition to the largest gaps in early afternoon and night, the figure shows that the coverages from DMSP-F16 (08.00) and Meteor-3M-N2 (09.15) are much overlapping.

4.0 Frequencies used for data transmission to the ground

This Chapter collects the information on frequency plans of GOS satellites limited to:

- current and planned operational meteorological satellites in geostationary and sunsynchronous orbits
- frequencies used to download or relay the observed data to the central system station(s) and to local user stations.

This information is already contained in the sections dealing with the individual satellites. The purpose of this section is to provide a friendly framework for keeping the information updated. The level of detail of the information provided is totally insufficient for station design, but may allow the reader to at least capture a broad idea of the complexity of each data acquisition mode.

4.1 Geostationary satellites

Table 4.1 reports frequency information for geostationary satellites. It is a simplified presentation, especially as concerns the transmission of raw data to the central facility (only one stream is mentioned, whereas generally there are more). Meteorological data distribution is indicated only when it implies a dedicated user station. Data Collection Platforms are mentioned only when requiring interrogation.

Table 4.1 – Frequency plan of meteorological satellites in geostationary orbit (end 2003)

Satellite	Utilisation	Position	Service	Frequency	Bandwidth	Polarisation	Data rate
Meteosat-5	1991-2004	63°E	to PGS	1686.833 MHz	.... MHz	Linear	333 kbps
			HRID	1694.5 MHz	1.5 MHz	Linear	166 kbps
			WEFAX-1	1694.5 MHz	1.5 MHz	Linear	1.6 kHz
			WEFAX-2	1691.0 MHz	1.5 MHz	Linear	1.6 kHz
			MDD	1695.74 MHz	120 kHz (4 channels)	Linear	2.4 kbps
Meteosat-6	1993-2005	10°E	to PGS	1686.833 MHz	.... MHz	Linear	333 kbps
			HRID	1694.5 MHz	1.5 MHz	Linear	166 kbps
			WEFAX-1	1694.5 MHz	1.5 MHz	Linear	1.6 kHz
			WEFAX-2	1691.0 MHz	1.5 MHz	Linear	1.6 kHz
			MDD	1695.74 MHz	120 kHz (4 channels)	Linear	2.4 kbps
Meteosat-7	1997-2005	0°	to PGS	1686.833 MHz	.... MHz	Linear	333 kbps
			HRID	1694.5 MHz	1.5 MHz	Linear	166 kbps
			WEFAX-1	1694.5 MHz	1.5 MHz	Linear	1.6 kHz
			WEFAX-2	1691.0 MHz	1.5 MHz	Linear	1.6 kHz
			MDD	1695.74 MHz	120 kHz (4 channels)	Linear	2.4 kbps
Meteosat-8 (MSG-1)	2002-2009	10.5°W	to PGS	1686.833 MHz	.... MHz	Linear	3.2 Mbps
			HRIT	1695.15 MHz	1.96 MHz	Linear	1.0 Mbps
			LRIT	1691.0 MHz	0.66 MHz	Linear	128 kbps
Meteosat-9 (MSG-2)	2005-2012	~ 0° (TBD)	to PGS	1686.833 MHz	.... MHz	Linear	3.2 Mbps
			HRIT	1695.15 MHz	1.96 MHz	Linear	1.0 Mbps
			LRIT	1691.0 MHz	0.66 MHz	Linear	128 kbps
Meteosat-10 (MSG-3)	2009-2016	~ 0° (TBD)	to PGS	1686.833 MHz	.... MHz	Linear	3.2 Mbps
			HRIT	1695.15 MHz	1.96 MHz	Linear	1.0 Mbps
			LRIT	1691.0 MHz	0.66 MHz	Linear	128 kbps
Meteosat-11 (MSG-4)	2011-2018	~ 0° (TBD)	to PGS	1686.833 MHz	.... MHz	Linear	3.2 Mbps
			HRIT	1695.15 MHz	1.96 MHz	Linear	1.0 Mbps
			LRIT	1691.0 MHz	0.66 MHz	Linear	128 kbps
GOES-8	1994-2004	165°E	to CDA	1676.2 MHz	6.0 MHz	Linear	3.0 Mbps
			GVAR	1685.7 MHz	5.0 MHz	Linear	2.1 Mbps
			WEFAX	1691.0 MHz	1.0 MHz	Linear	1.6 kHz
			DCIS-1	468.8250 MHz	200 kHz	RHC	100 kbps
			DCIS-2	468.8375 MHz	200 kHz	RHC	100 kbps

Table 4.1 (cont.) – Frequency plan of meteorological satellites in geostationary orbit (end 2003)

Satellite	Utilisation	Position	Service	Frequency	Bandwidth	Polarisation	Data rate
GOES-9	1995-2004	155°E	to CDA	1676.2 MHz	6.0 MHz	Linear	3.0 Mbps
			GVAR	1685.7 MHz	5.0 MHz	Linear	2.1 Mbps
			WEFAX	1691.0 MHz	1.0 MHz	Linear	1.6 kHz
			DCIS-1	468.8250 MHz	200 kHz	RHC	100 kbps
			DCIS-2	468.8375 MHz	200 kHz	RHC	100 kbps
GOES-10	1997-2005	135°W	to CDA	1676.2 MHz	6.0 MHz	Linear	3.0 Mbps
			GVAR	1685.7 MHz	5.0 MHz	Linear	2.1 Mbps
			WEFAX	1691.0 MHz	1.0 MHz	Linear	1.6 kHz
			DCIS-1	468.8250 MHz	200 kHz	RHC	100 kbps
			DCIS-2	468.8375 MHz	200 kHz	RHC	100 kbps
GOES-11	2000-2007	105°W	to CDA	1676.2 MHz	6.0 MHz	Linear	3.0 Mbps
			GVAR	1685.7 MHz	5.0 MHz	Linear	2.1 Mbps
			WEFAX	1691.0 MHz	1.0 MHz	Linear	1.6 kHz
			DCIS-1	468.8250 MHz	200 kHz	RHC	100 kbps
			DCIS-2	468.8375 MHz	200 kHz	RHC	100 kbps
GOES-12	2001-2008	75°W	to CDA	1676.2 MHz	6.0 MHz	Linear	3.0 Mbps
			GVAR	1685.7 MHz	5.0 MHz	Linear	2.1 Mbps
			WEFAX	1691.0 MHz	1.0 MHz	Linear	1.6 kHz
			DCIS-1	468.8250 MHz	200 kHz	RHC	100 kbps
			DCIS-2	468.8375 MHz	200 kHz	RHC	100 kbps
GOES-13 (GOES-N)	2004-2011	TBD	to CDA	1676.2 MHz	6.0 MHz	Linear	3.0 Mbps
			GVAR	1685.7 MHz	5.0 MHz	Linear	2.1 Mbps
			WEFAX	1691.0 MHz	1.0 MHz	Linear	1.6 kHz
			DCIS-1	468.8250 MHz	200 kHz	RHC	100 kbps
			DCIS-2	468.8375 MHz	200 kHz	RHC	100 kbps
GOES-14 (GOES-O)	2007-2014	TBD	to CDA	1676.2 MHz	6.0 MHz	Linear	3.0 Mbps
			GVAR	1685.7 MHz	5.0 MHz	Linear	2.1 Mbps
			WEFAX	1691.0 MHz	1.0 MHz	Linear	1.6 kHz
			DCIS-1	468.8250 MHz	200 kHz	RHC	100 kbps
			DCIS-2	468.8375 MHz	200 kHz	RHC	100 kbps
GOES-15 (GOES-P)	2008-2015	TBD	to CDA	1676.2 MHz	6.0 MHz	Linear	3.0 Mbps
			GVAR	1685.7 MHz	5.0 MHz	Linear	2.1 Mbps
			WEFAX	1691.0 MHz	1.0 MHz	Linear	1.6 kHz
			DCIS-1	468.8250 MHz	200 kHz	RHC	100 kbps
			DCIS-2	468.8375 MHz	200 kHz	RHC	100 kbps
MTSAT-1	2004-2012	140°E	to CDAS	.... MHz	.... MHz	Linear	.... Mbps
			HiRID	1687.1 MHz	2.0 MHz	Linear	660 kbps
			HRPT	1687.1 MHz	5.3 MHz	Linear	3.5 Mbps
			WEFAX	1691.0 MHz	250 kHz	Linear	1.6 kHz
			LRIT	1691.0 MHz	250 kHz	Linear	75 kbps
			DCS	.... MHz	.... kHz	Linear	100 kbps
MTSAT-2	2005-2014	TBD	to CDAS	.... MHz	.... MHz	Linear	.... Mbps
			HRPT	1687.1 MHz	5.3 MHz	Linear	3.5 Mbps
			LRIT	1691.0 MHz	250 kHz	Linear	75 kbps
			DCS	.... MHz	.... kHz	Linear	100 kbps
GOMS-N2	2006-2015	76°E	to CDA	.... MHz	.... MHz	Linear	.... Mbps
			HRPT	1685.0 MHz	.... MHz	Linear	.... Mbps
			WEFAX	1691.0 MHz	.... kHz	Linear	1.6 kHz
			LRIT	1691.0 MHz	.... kHz	Linear	.... kbps
			DCS	469.0 MHz	.... kHz	RHC	100 kbps

Table 4.1 (cont.) – Frequency plan of meteorological satellites in geostationary orbit (end 2003)

Satellite	Utilisation	Position	Service	Frequency	Bandwidth	Polarisation	Data rate
FY-2A	1997-2004	86.5°E	to CDAS	.... MHz	.... MHz	Linear	14 Mbps
			S-VISSR	1687.5 MHz	2.0 MHz	Linear	660 kbps
			WEFAX	1691.0 MHz	260 kHz	Linear	1.6 kHz
FY-2B	2000-2006	105°E	to CDAS	.... MHz	.... MHz	Linear	14 Mbps
			S-VISSR	1687.5 MHz	2.0 MHz	Linear	660 kbps
			WEFAX	1691.0 MHz	260 kHz	Linear	1.6 kHz
FY-2C	2004-2009	TBD	to CDAS	.... MHz	.... MHz	Linear	14 Mbps
			S-VISSR	1687.5 MHz	2.0 MHz	Linear	660 kbps
			LRIT	1691.0 MHz	260 kHz	Linear	...... kbps
FY-2D	2006-2011	TBD	to CDAS	.... MHz	.... MHz	Linear	14 Mbps
			S-VISSR	1687.5 MHz	2.0 MHz	Linear	660 kbps
			LRIT	1691.0 MHz	260 kHz	Linear	...... kbps
FY-2E	2009-2014	TBD	to CDAS	.... MHz	.... MHz	Linear	14 Mbps
			S-VISSR	1687.5 MHz	2.0 MHz	Linear	660 kbps
			LRIT	1691.0 MHz	260 kHz	Linear	...... kbps
INSAT-2B	1993-2004	111.5°E	to CDAS	.... MHz	.... MHz	Linear	.... Mbps
			MDD	2599.225 MHz	.... kHz	Linear	10 kHz
INSAT-2E	1999-2004	83°E	to CDAS	.... MHz	.... MHz	Linear	.... Mbps
			MDD	2599.225 MHz	.... kHz	Linear	10 kHz
INSAT-3A	2003-2008	92.5°E	to CDAS	.... MHz	.... MHz	Linear	.... Mbps
			MDD	2599.225 MHz	.... kHz	Linear	10 kHz
INSAT-3D	2006-2010	TBD	to CDAS	.... MHz	.... MHz	Linear	.... Mbps
			HRIT	.... MHz	.... kHz	Linear	...... kbps
			LRIT	1691.0 MHz	.... kHz	Linear	...... kbps
Kalpana-1	2002-2007	74°E	to CDAS	.... MHz	.... MHz	Linear	.... Mbps
			MDD	2599.225 MHz	.... kHz	Linear	10 kHz
Kalpana-2	2006-2010	TBD	to CDAS	.... MHz	.... MHz	Linear	.... Mbps
			MDD	2599.225 MHz	.... kHz	Linear	10 kHz

4.2 Sunsynchronous satellites

Table 4.2 reports frequency information for sunsynchronous satellites. It is a simplified presentation, especially as concerns the transmission of global data to the high-latitude Command and Data Acquisition stations (only one stream is mentioned, whereas generally there are more). Data Collection Platforms are mentioned only when requiring interrogation. DMSP satellites are not included since the ordinary way to input their data into GOS is through NOAA or by bilateral agreements.

Table 4.2 – Frequency plan of meteorological satellites in sunsynchronous orbit (end 2003)

Satellite	Utilisation	LST	Service	Frequency	Bandwidth	Polarisation	Data rate
NOAA-15	1998-2004	06.30 d 18.30 a	GAC/LAC	1702.5 and 1698 or 1707 MHz	2.66 MHz	LHC or RHC	2.66 Mbps
			HRPT	1698 MHz	2.66 MHz	RHC	665.4 kbps
			HRPT bkp	1702.5 MHz	2.66 MHz	LHC	665.4 kbps
			APT	137.5 or 137.62 MHz	34 kHz	RHC	2.1 kHz
			DSB	137.35 or 137.77 MHz	.... kHz	RHC	8.32 kbps
NOAA-16	2000-2005	02.15 d 14.15 a	GAC/LAC	1702.5 and 1698 or 1707 MHz	2.66 MHz	LHC or RHC	2.66 Mbps
			HRPT	1698 MHz	2.66 MHz	RHC	665.4 kbps
			HRPT bkp	1702.5 MHz	2.66 MHz	LHC	665.4 kbps
			APT	failed			
			DSB	137.35 or 137.77 MHz	.... kHz	RHC	8.32 kbps

Table 4.2 (cont.) – Frequency plan of meteorological satellites in sunsynchronous orbit (end 2003)

Satellite	Utilisation	LST	Service	Frequency	Bandwidth	Polarisation	Data rate
NOAA-17	2002-2006	10.20 d 22.20 a	GAC/LAC	1702.5 and 1698 or 1707 MHz	2.66 MHz	LHC or RHC	2.66 Mbps
			HRPT	1698 MHz	2.66 MHz	RHC	665.4 kbps
			HRPT bkp	1702.5 MHz	2.66 MHz	LHC	665.4 kbps
			APT	137.5 or 137.62 MHz	34 kHz	RHC	2.1 kHz
			DSB	137.35 or 137.77 MHz	.... kHz	RHC	8.32 kbps
NOAA-18 (NOAA-N)	2004-2008	02.00 d 14.00 a (TBC)	GAC/LAC	1702.5 and 1698 or 1707 MHz	2.66 MHz	LHC or RHC	2.66 Mbps
			HRPT	1698 MHz	2.66 MHz	RHC	665.4 kbps
			HRPT bkp	1702.5 MHz	2.66 MHz	LHC	665.4 kbps
			APT	137.5 or 137.62 MHz	34 kHz	RHC	2.1 kHz
			DSB	137.35 or 137.77 MHz	.... kHz	RHC	8.32 kbps
NOAA-19 (NOAA-N')	2008-2012	02.00 d 14.00 a (TBC)	GAC/LAC	1702.5 and 1698 or 1707 MHz	2.66 MHz	LHC or RHC	2.66 Mbps
			HRPT	1698 MHz	2.66 MHz	RHC	665.4 kbps
			HRPT bkp	1702.5 MHz	2.66 MHz	LHC	665.4 kbps
			APT	137.5 or 137.62 MHz	34 kHz	RHC	2.1 kHz
			DSB	137.35 or 137.77 MHz	.... kHz	RHC	8.32 kbps
NPP	2006-2011	10.30 d 22.30 a	SMD	8212.5 MHz	375 MHz	RHC	300 Mbps
			HRD	7812 MHz	30.8 MHz	RHC	15 Mbps
NPOESS-1	2009-2016	09.30 d 21.30 a	SMD	25.65 GHz	300 MHz	RHC	150 Mbps
			HRD	7812 or 7830 MHz	30.8 MHz	RHC	20 Mbps
			LRD	1706	8 MHz	RHC	3.88 Mbps
NPOESS-2	2011-2018	01.30 d 13.30 a	SMD	25.65 GHz	300 MHz	RHC	150 Mbps
			HRD	7812 or 7830 MHz	30.8 MHz	RHC	20 Mbps
			LRD	1706	8 MHz	RHC	3.88 Mbps
NPOESS-3	2013-2020	05.30 d 17.30 a	SMD	25.65 GHz	300 MHz	RHC	150 Mbps
			HRD	7812 or 7830 MHz	30.8 MHz	RHC	20 Mbps
			LRD	1706	8 MHz	RHC	3.88 Mbps
NPOESS-4	2015-2022	09.30 d 21.30 a	SMD	25.65 GHz	300 MHz	RHC	150 Mbps
			HRD	7812 or 7830 MHz	30.8 MHz	RHC	20 Mbps
			LRD	1706	8 MHz	RHC	3.88 Mbps
NPOESS-5	2018-2025	01.30 d 13.30 a	SMD	25.65 GHz	300 MHz	RHC	150 Mbps
			HRD	7812 or 7830 MHz	30.8 MHz	RHC	20 Mbps
			LRD	1706	8 MHz	RHC	3.88 Mbps
NPOESS-6	2019-2026	05.30 d 17.30 a	SMD	25.65 GHz	300 MHz	RHC	150 Mbps
			HRD	7812 or 7830 MHz	30.8 MHz	RHC	20 Mbps
			LRD	1706	8 MHz	RHC	3.88 Mbps
MetOp-1	2005-2010	09.30 d 21.30 a	GDS	7800 MHz	63 MHz	RHC	70 Mbps
			AHRPT	1701.3 MHz (1707 MHz bkp)	4.5 MHz	RHC	3.5 Mbps
			LRPT	137.9 MHz	150 kHz	RHC	72 kbps
MetOp-2	2010-2015	09.30 d 21.30 a	GDS	7800 MHz	63 MHz	RHC	70 Mbps
			AHRPT	1701.3 MHz (1707 MHz bkp)	4.5 MHz	RHC	3.5 Mbps
			LRPT	137.9 MHz	150 kHz	RHC	72 kbps
MetOp-3	2014-2020	09.30 d 21.30 a	GDS	7800 MHz	63 MHz	RHC	70 Mbps
			AHRPT	1701.3 MHz (1707 MHz bkp)	4.5 MHz	RHC	3.5 Mbps
			LRPT	137.9 MHz	150 kHz	RHC	72 kbps
Meteor-3M N1	2001-2005	09.15 d 21.15 a	CDA	8192 GHz	32 MHz	RHC	15.4 Mbps
			HRPT-like	1700 GHz	2 MHz	RHC	665 kbps
Meteor-3M N2	2005-2009	09.15 d 21.15 a	CDA	8192 GHz	32 MHz	RHC	15.4 Mbps
			HRPT	1700 GHz	2 MHz	RHC	665 kbps
			LRPT	137.9 or 137.1 GHz	150 kHz	RHC	64 kbps
Meteor-3M N3	2008-2012	09.15 d 21.15 a	CDA	8192 GHz	32 MHz	RHC	15.4 Mbps
			HRPT	1700 GHz	2 MHz	RHC	665 kbps
			LRPT	137.9 or 137.1 GHz	150 kHz	RHC	64 kbps

Table 4.2 (cont.) – Frequency plan of meteorological satellites in sunsynchronous orbit (end 2003)

Satellite	Utilisation	LST	Service	Frequency	Bandwidth	Polarisation	Data rate
FY-1C	1999-2004	6.45 d	CDPT	1708.5 MHz (1695.5 MHz bkp)	5.6 MHz	RHC	1.33 Mbps
		18.45 a	CHRPT	1700.5 MHz (1704.5 GHz bkp)	5.6 MHz	RHC	1.33 Mbps
FY-1D	2002-2006	8.30 d	CDPT	1708.5 MHz (1695.5 MHz bkp)	5.6 MHz	RHC	1.33 Mbps
		20.40 a	CHRPT	1700.5 MHz (1704.5 GHz bkp)	5.6 MHz	RHC	1.33 Mbps
FY-3A	2006-2009	10.00 d 22.00 a	DPT	8025-8215 MHz or 8215-8400 MHz	120 MHz	RHC	93 Mbps
			MPT	7750-7850 MHz	35 MHz	RHC	18.2 Mbps
			AHRPT	1698-1710 MHz	5.6 MHz	RHC	4.2 Mbps
FY-3B	2008-2011	10.00 d 22.00 a	DPT	8025-8215 MHz or 8215-8400 MHz	120 MHz	RHC	93 Mbps
			MPT	7750-7850 MHz	35 MHz	RHC	18.2 Mbps
			AHRPT	1698-1710 MHz	5.6 MHz	RHC	4.2 Mbps
FY-3C	2010-2013	10.00 d 22.00 a	DPT	8025-8215 MHz or 8215-8400 MHz	120 MHz	RHC	93 Mbps
			MPT	7750-7850 MHz	35 MHz	RHC	18.2 Mbps
			AHRPT	1698-1710 MHz	5.6 MHz	RHC	4.2 Mbps
FY-3D	2012-2015	10.00 d 22.00 a	DPT	8025-8215 MHz or 8215-8400 MHz	120 MHz	RHC	93 Mbps
			MPT	7750-7850 MHz	35 MHz	RHC	18.2 Mbps
			AHRPT	1698-1710 MHz	5.6 MHz	RHC	4.2 Mbps
FY-3E	2014-2017	10.00 d 22.00 a	DPT	8025-8215 MHz or 8215-8400 MHz	120 MHz	RHC	93 Mbps
			MPT	7750-7850 MHz	35 MHz	RHC	18.2 Mbps
			AHRPT	1698-1710 MHz	5.6 MHz	RHC	4.2 Mbps
FY-3F	2016-2019	10.00 d 22.00 a	DPT	8025-8215 MHz or 8215-8400 MHz	120 MHz	RHC	93 Mbps
			MPT	7750-7850 MHz	35 MHz	RHC	18.2 Mbps
			AHRPT	1698-1710 MHz	5.6 MHz	RHC	4.2 Mbps
FY-3G	2018-2021	10.00 d 22.00 a	DPT	8025-8215 MHz or 8215-8400 MHz	120 MHz	RHC	93 Mbps
			MPT	7750-7850 MHz	35 MHz	RHC	18.2 Mbps
			AHRPT	1698-1710 MHz	5.6 MHz	RHC	4.2 Mbps

Definition of spectral bands

In this Report use has been made of spectral band definitions which are not fully standardised. Therefore, the following two tables list these definitions as used here. Two tables are provided, one for the bands used for Remote Sensing, one for the sub-division of the band used in radar technology. It should be noted that the band definitions do not conform to those used in the CEOS/WMO database. Differences exits for the limits for UV (0.01 µm - 0.40 µm), VIS (0.4 µm - 0.75 µm), NIR (0.75 - 1.3 µm) and MW (1.0 cm – 100 cm). Sub-mm, SW, LW, IR and VNIR are not defined in the CEOS/WMO database.

Bands of the electromagnetic spectrum exploited for Remote Sensing

UV	Ultra-Violet	0.01 - 0.38 µm
VIS	Visible	0.38 - 0.78 µm
NIR	Near Infra-Red	0.78 - 1.30 µm
SWIR	Short-Wave Infra-Red	1.30 – 3.00 µm
MWIR	Medium-Wave Infra-Red	3.00 – 6.00 µm
TIR	Thermal Infra-Red	6.00 – 15.0 µm
FIR	Far Infra-Red	15 µm - 1 mm (= 300 GHz)
Sub-mm	Submillimetre wave (part of FIR)	3000 - 300 GHz (or 100 µm - 1 mm)
MW	Microwave	300 - 1 GHz (or 1 mm - 30 cm)
SW	Short Wave	0.2 - 4.0 µm
LW	Long Wave	4 - 100 µm
IR	Infra-Red (MWIR + TIR)	3 - 15 µm
VNIR	Visible and Near Infra-Red (VIS + NIR)	0.38 - 1.3 µm

Bands used in radar technology
(according to ASPRS, American Society for Photogrammetry and Remote Sensing)

Band	Frequency range	Wavelength range
P	220 - 390 MHz	77 -136 cm
UHF	300 - 1000 MHz	30 -100 cm
L	1 - 2 GHz	15 - 30 cm
S	2 - 4 GHz	7.5 - 15 cm
C	4 - 8 GHz	3.75 - 7.5 cm
X	8 – 12.5 GHz	2.4 - 3.75 cm
Ku	12.5 - 18 GHz	1.67 - 2.4 cm
K	18 - 26.5 GHz	1.18 - 1.67 cm
Ka	26.5 - 40 GHz	0.75 - 1.18 cm
V	40 - 75 GHz	4.0 - 7.5 mm
W	75 - 110 GHz	2.75 - 4.0 mm

List of acronyms (except for instruments)

(Instrument acronyms are included in the initial Table of the Appendix, with some exception)

AMP	Applications of Meteorology Programme
APT	Automatic Picture Transmission
AREP	Atmospheric Research and Environment Programme
ATN	Advanced TIROS-N
ATOVS	Advanced TIROS Operational Vertical Sounder
ATS	Application Technology Satellite
CDA	Command and Data Acquisition station
CDAS	Command and Data Acquisition Station
CDPT	China Delayed Picture Transmission
CERES	Clouds and the Earth's Radiant Energy System
CGMS	Coordination Group for Meteorological Satellites
CHRPT	China High Resolution Picture Transmission
CMA	China Meteorological Department
CNES	Centre National d'Etudes Spatiales
CNSA	China National Space Agency
DCP	Data Collection Platform
DMSP	Defense Meteorological Satellite Program
DPT	Delayed Picture Transmission
DSB	Direct Sounder Broadcast
DVB	Digital Video Broadcast
EOS	Earth Observing System
EPS	EUMETSAT Polar System
ERS	European Remote-sensing Satellite
ESA	European Space Agency
ESSA	Environmental Science and Services Administration
ESSP	Earth System Science Pathfinder program
EUMETSAT	European Organisation for the exploitation of meteorological satellites
FGGE	First GARP Global Experiment
FY	Feng-Yun (FY-1 and FY-3 sunsynchronous, FY-2 geostationary)
G/T	Overall merit figure of a receiving system (dB/K)
GAC	Global Area Coverage
GARP	Global Atmospheric Research Programme
GDS	Global Data Stream
GEO	Geostationary Earth Orbit
GMS	Geosynchronous Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
GOMS	Geostationary Operational Meteorological Satellite
GOS	Global Observing System
HiRID	High Resolution Imager Data
HRIDS	High Resolution Image Dissemination Service
HRIT	High Rate Information Transmission
HRPT	High Resolution Picture Transmission
HRUS	High Rate User Station
HWRP	Hydrology and Water Resources Programme

IFOV	Instantaneous Field Of View
IMD	India Meteorological Department
INDOEX	Indian Ocean Experiment
INSAT	Indian National Satellite
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
ISRO	India Space Research Organisation
ITOS	Improved TIROS Operational System
JAXA	Japan Aerospace Exploration Agency (formerly NASDA)
JMA	Japan Meteorological Agency
JPS	Joint Polar System
LAC	Local Area Coverage
LEO	Low Earth Orbit
LRIT	Low Rate Information Transmission
LRUS	Low Rate User Station
LST	Local Solar Time
MAP	Mesoscale Alpine Programme
MDD	Meteorological Data Distribution
MDUS	Medium-scale Data Utilisation Station
MetSat	Meteorological Satellite (re-named Kalpana-1)
MOP	Meteosat Operational Programme
MPT	M......... Picture Transmission
MSG	Meteosat Second Generation
MTG	Meteosat Third Generation
MTP	Meteosat Transition Programme
MTSAT	Multi-functional Transport Satellite
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Program
NWP	Numerical Weather Prediction
PDUS	Primary Data User Station
PGS	Primary Ground Station
POEM	Polar Orbit Earth-observation Mission
POES	Polar-orbiting Operational Environmental Satellite
R & D	Research and Development
ROSAVIAKOSMOS	Aeronautics and Space Agency of the Russian Federation
ROSHYDROMET	Hydro-Meteorological Service of the Russian Federation
SAR	Synthetic Aperture Radar
SDUS	Secondary Data User Station
SMD	Stored Mission Data
SMS	Synchronous Meteorological Satellite
SNR	Signal-to-Noise Ratio
SSP	Sub Satellite Point
TIROS	Television and Infra-Red Observation Satellite
TOS	TIROS Operational System
TOVS	TIROS Operational Vertical Sounder
WCP	World Climate Programme
WCRP	World Climate Research Programme
WEFAX	Weather Facsimile
WMO	World Meteorological Organization
WWW	World Weather Watch

APPENDIX

INSTRUMENTS OF THE SPACE BASED COMPONENT OF GOS

This document reports, in ***Table 1***, the list of all instruments that have been flown, or currently are being flown, or are planned to be flown, on the satellites constituting the space-based component of the Global Observing System (GOS). Data transmission and orbitography/navigation systems are not included. The Table records the corresponding satellites and the period of utilisation of the instrument through the various satellites of a series.

Instrument sheets follow (only for *Earth sensors*, i.e., not for *in situ* environment monitoring at platform level, solar observation, data collection systems, data distribution and search & rescue), limited to current and planned instruments. The instruments for which sheets are provided are marked in the last column of Table 1 and reported in ***Table 2***.

The instrument sheets collect the information as available up to 31 December 2003, following meetings of the Coordination Group for Meteorological Satellites (CGMS) (last: CGMS-XXXI, Ascona 10-13 November 2003) widely integrated by consulting other sources of public domain (generally the Web including the WMO/CEOS Database of User requirements and Space capabilities, other WMO documents including WMO No. 411 and books). In extreme cases personal notes were used.

The degree of detail of the various instrument sheets changes with the priority of the mission in respect of WMO objectives (first priority: imagery and sounding), with the development status (from operational to planned) and with the availability of information.

When, for an instrument, there are upgraded flight models co-existing with previous flight models, the instrument sheet reports the latest version, even if the satellite has not yet been launched.

The purpose of this Appendix is to constitute a framework to facilitate updating of information exchanged within CGMS. The instrument sheets can be regarded as templates providing guidance for checking the current content, updating as necessary, and filling possible gaps. Consultation of sheets of similar instruments may be helpful when focusing on an instrument sheet to be filled. Table 2 is structured so as to facilitate identifying the instruments that belong to the same category.

The information collected in this document has been used in the Main Text of the Report to compare the degree of service provided by the various satellites concurring to implement GOS so as to control whether the composite system is not only compliant with requirements in terms of number and distribution of satellites, ma also in terms of homogeneity of data quality from different sources supposed to be used in combination.

The current issue (end 2003) only includes instruments of the "classical" meteorological satellites, i.e.:

- in geostationary orbit: Meteosat, GOES, GOMS, MTSAT, INSAT, Kalpana and FY-2;
- in sunsynchronous orbit: NOAA/NPOESS, MetOp, Meteor, FY-1/FY-3, and DMSP (limited to microwave instruments whose data are operationally available through NOAA and currently used).

Future issues will include instruments of certain R&D satellites that are or will be included in the expanded GOS according to the newly-established *WMO Space Programme* and by commitments to WMO by R&D agencies.

Table 1 - List of instruments, corresponding satellites and utilisation period

Acronym	Full name	Satellites	Utilisation	Sheet
ABI	Advanced Baseline Imager	GOES-R and follow-on	20012 →	X
AC	Radiation Budget Sensor	Meteor-1 1 to 28	1969-1978	
ALT	Radar Altimeter	NPOESS-3/6	2013-2026	X
AMSU-A	Advanced Microwave Sounding Unit - A	NOAA 15 to 19 MetOp 1/2	1998-2012 2005-2010	X
AMSU-B	Advanced Microwave Sounding Unit - B	NOAA-15/16/17	1998-2006	X
APS	Aerosol Polarimetry Sensor	NPOESS-1/4	2009-2022	X
APT	Automatic Picture Transmission	TIROS-8, ESSA-2/4/6/8 ITOS-1, NOAA-1	1967-1976 1970-1971	
ARGOS-DCS	ARGOS Data Collection and localisation System	TIROS-N, NOAA 6 to 19 NPOESS-1/3/4/6 MetOp 1 to 3	1978-2012 2006-2026 2005-2019	
ASCAT	Advanced Scatterometer	MetOp 1/2/3	2005-2019	X
ATMS	Advanced Technology Microwave Sounder	NPP, NPOESS-1/3/4/6	2006-2026	X
AVCS	Advanced Vidicon Camera System	ESSA-3/5/7/9, ITOS-1, NOAA-1	1966-1971	
AVHRR/3	Advanced Very High Resolution Radiometer	TIROS-N, NOAA 6 to 19 MetOp-1/2	1978-2012 2005-2019	X
CCD	Charge Coupled Device Camera	INSAT-2E, INSAT-3A	1999-2008	X
CMIS	Conical-scanning Microwave Imager/Sounder	NPOESS 1 to 6	2009-2026	X
CrIS	Cross-track Infrared Sounder	NPP, NPOESS-1/3/4/6	2006-2026	X
DCIS	Data Collection and Interrogation Service	SMS-1/2, GOES 1 to 15 GOMS-1/2 and follow-on	1974-2015 1994 →	
DCS	Data Collection Service	Meteosat 1 to 11 GMS 1 to 5, MTSAT-1/2 FY-2 A to E INSAT-1A to 3D, Kalpana 1/2	1977-2018 1977-2014 1997-2014 1982-2010	
ERBE	Earth Radiation Budget Experiment	NOAA-9 and NOAA-10	1984-2001	
ERBS	Earth Radiation Budget Sensor	NPOESS-2/5	2011-2025	X
FPR	Flat Plate Radiometer	TIROS-2/3/4/7, ESSA-1/3/5/7/9 ITOS-1, NOAA-1	1960-1972 1970-1971	
GEOSAR	Geostationary Search and Rescue	GOES 8 to 15 Meteosat 8 to 11 (MSG) INSAT-3 A and D GOMS-N2 and follow-on	1994-2015 2002-2018 2003-2010 2006 →	
GERB	Geostationary Earth Radiation Budget	Meteosat 8 to 11 (MSG)	2002-2018	X
GGAK-M	Space Environment Monitor	Meteor-3M 2/3	2005-2012	
GOME-2	Global Ozone Monitoring Experiment - 2	MetOp 1/2/3	2005-2019	X
GPSOS	Global Positioning System Occultation Sensor	NPOESS-2/5	2011-2025	X
GRAS	GNSS Receiver for Atmospheric Sounding	MetOp 1/2/3	2005-2019	X
GVHHR	Geostationary Very High Resolution Radiometer	ATS-6	1974	
HES	Hyperspectral Environmental Suite	GOES-R and follow-on	20012 →	X
HIRS/4	High-resolution Infra Red Sounder	TIROS-N, NOAA 6 to 19 MetOp-1/2	1978-2012 2005-2019	X
IASI	Infrared Atmospheric Sounding Interferometer	MetOp 1/2/3	2005-2019	X
IMAGER	GOES Imager INSAT Imager	GOES 8 to 15 INSAT-3D	1994-2015 2006-2010	X X
IR	Infrared Instrument	Meteor-1 1 to 28, Meteor-2 1 to 22	1969-1994	
IRAS	Infra Red Atmospheric Sounder	FY-3 1 to 7	2006-2021	X
IRFS-2	IR Sounding Spectrometer	Meteor-3M 2/3	2005-2012	X
JAMI	Japanese Advanced Meteorological Imager	MTSAT 1/2	2004-2014	X
KGI-4C	Space Environment Monitor (particles)	Meteor-3M 1	2001-2005	
Klimat	Infrared Imaging Radiometer	Meteor-3 1 to 7, Meteor-3M 1	1985-2005	X
KMSS	High-resolution VIS/NIR radiometer	Meteor-3M 2/3	2005-2012	

Table 1 (cont.) – List of instruments, corresponding satellites and utilisation period

Acronym	Full name	Satellites	Utilisation	Sheet
LMS	Lightning Mapper Sensor	GOES-R and follow-on	20012 →	X
MERSI	Medium Resolution Spectral Imager	FY-3 A to G	2006-2021	X
MHS	Microwave Humidity Sounding	NOAA-18/19 MetOp ½/3	2004-2012 2005-2019	X
MIVZA	Imaging Microwave Radiometer	Meteor-3M 1	2001-2005	X
MR-2000M	Television Camera	Meteor-3 1 to 7, Meteor-3M 1	1985-2005	X
MR-900B	Television Camera	Meteor-3 1 to 7	1985-1995	
MRIR	Medium Resolution Infrared Radiometer	TIROS-2/3/4/7	1960-1967	
MSGI-5EI	Space Environment Monitor (irradiances)	Meteor-3M 1	2001-2005	
MSSCC	Multi-color Spin Scan Cloud Camera	ATS-3	1967-1975	
MSU	Microwave Sounding Unit	TIROS-N, NOAA 6 to 14	1978-2003	
MSU-E	High-resolution VIS/NIR radiometer	Meteor-3M 1	2001-2005	
MSU-G	GOMS Imager	GOMS-2 and follow-on	2006 →	X
MSU-MR	VIS/IR Imaging Radiometer	Meteor-3M 2/3	2005-2012	X
MTG imager(s)	TBD	Meteosat Third Generation	2015 →	X
MTG lightning	TBD	Meteosat Third Generation	2015 →	X
MTG sounder	TBD	Meteosat Third Generation	2015 →	X
MTVZA	Imaging/Sounding Microwave Radiometer	Meteor-3M 1 and 2/3	2001-2009	X
MVIRI	Meteosat Visible Infra-Red Imager	Meteosat 1 to 7	1977-2005	X
MVISR	Multichannel Visible Infrared Scanning Radiometer	FY-1 A to D	1988-2006	X
MWHS	Micro-Wave Humidity Sounder	FY-3 A to G	2006-2021	X
MWRI	Micro-Wave Radiation Imager	FY-3 A to G	2006-2021	X
MWTS	Micro-Wave Temperature Sounder	FY-3 A to G	2006-2021	X
OMPS	Ozone Mapping and Profiler Suite	NPP, NPOESS-2/5	2006-2025	X
Radiomet	Radio-occultation sounder	Meteor-3M 2/3	2005-2012	X
RMK-2	Space Environment Monitor	Meteor-2 1 to 22, Meteor-3 1 to 6	1975-1994	
RMS	Radiation Measurement System	GOMS-1/2 and follow-on	1994 →	
SAGE-III	Stratospheric Aerosol and Gas Experiment – III	Meteor-3M 1	2001-2005	X
SARSAT	Search and Rescue Satellite-Aided Tracking System	NOAA 8 to 19. except 12 NPOESS 1 to 6 MetOp 1 to 3	1983-2012 2009-2026 2005-2019	
SBUV/2	Solar Backscatter Ultraviolet / 2	NOAA 9 to 19 except 12/15	1984-2012	X
ScaRaB	Scanner for Radiation Budget	Meteor-3 7	1994-1995	
SEM (in GEO)	Space Environment Monitor	SMS-1/2, GOES 1 to 15 GMS 1 to 5 FY-2 A to E	1974-2015 1977-2003 1997-2014	
SEM (in LEO)	Space Environment Monitor	TIROS-N, NOAA 6 to 19 MetOp 1 to 3 FY-1 A to D, FY-3 A to G	1978-2012 2005-2019 1988-2021	
SESS	Space Environment Sensor Suite	NPOESS-2/5	2011-2025	
Severjanin	X-band Synthetic Aperture Radar	Meteor-3M 2/3	2005-2012	
SEVIRI	Spinning Enhanced Visible Infra-Red Imager	Meteosat 8 to 11 (MSG)	2002-2018	X
SFM-2	Ultraviolet spectrometer	Meteor-3M 1	2001-2005	X
SM	Infrared Sounding Radiometer	Meteor-2 1 to 22	1975-1994	
SOUNDER	GOES Sounder INSAT Sounder	GOES 8 to 15 INSAT-3D	1994-2015 2006-2010	X X
SPM	Solar Proton Monitor	NOAA 2 to 5	1972-1979	
SR	Scanning Radiometer	ITOS-1, NOAA 1 to 5	1970-1979	
SSCC	Spin Scan Cloud Camera	ATS-1	1966-1972	
SSM/I	Special Sensor Microwave – Imager	DMSP F 8/10/11/13/14/15	1987-2005	X
SSM/T	Special Sensor Microwave – Temperature	DMSP F 4 to 15	1979-2005	X
SSM/T2	Special Sensor Microwave – Humidity	DMSP F-11/12/14/15	1991-2005	X
SSMIS	Special Sensor Microwave – Imager/Sounder	DMSP F 16 to 20	2003-2015	X

Table 1 (cont.) – List of instruments, corresponding satellites and utilisation period

Acronym	Full name	Satellites	Utilisation	Sheet
SSU	Stratospheric Sounding Unit	TIROS-N, NOAA 6 to 14	1978-2003	
STR	Scanning TV Radiometer	GOMS-1	1994-2000	
S-VISSR	Stretched Visible-Infrared Spin Scan Radiometer	FY-2 A to E	1997-2014	X
SXI	Solar X-ray Imager	GOES 12 to 15	2001-2015	
TOMS	Total Ozone Mapping Spectrometer	Meteor-3 6	1991-1993	
TOU/SBUS	Total Ozone Unit & Solar Backscatter Ultraviolet Sounder	FY-3 A to G	2006-2021	X
TSIS	Total Solar Irradiance Sensor	NPOESS-3/6	2013-2026	
TV	Television Camera	Meteor-1 1 to 28, Meteor-2 1 to 22	1969-1994	
VAS	VISSR Atmospheric Sounder	GOES 4 to 7	1980-1995	
VCS	Vidicon Camera System	TIROS 1 to 10, ESSA-1	1960-1967	
VHRR (in GEO)	Very High Resolution Radiometer	INSAT-1A to 3A, Kalpana 1/2	1982-2010	X
VHRR (in LEO)	Very High Resolution Radiometer	NOAA 2 to 5	1972-1979	
VIIRS	Visible/Infrared Imager Radiometer Suite	NPP, NPOESS 1 to 6	2006-2026	X
VIRI-M	Visible Infra Red Imager for MetOp	MetOp-3	2015-2019	X
VIRR	Visible and Infra Red Radiometer	FY-3 A to G	2006-2021	X
VISSR	Visible-Infrared Spin Scan Radiometer	SMS-1/2, GOES-1/2/3 GMS 1 to 5	1974-1980 1977-2003	
VTPR	Vertical Temperature Profile Radiometer	NOAA 2 to 5	1972-1979	

Table 2 – List of the provided instrument sheets ordered by type of sensor and satellite

GEOSTATIONARY	Meteosat	GOES	GOMS-2	INSAT-3A and 3D	Kalpana	FY-2	MTSAT
Imager	MVIRI, SEVIRI	IMAGER	MSU-G	VHRR, CCD, IMAGER	VHRR	S-VISSR	JAMI
Advanced imager	MTG Imager	ABI					
Sounder		SOUNDER		SOUNDER			
Advanced sounder	MTG Sounder	HES					
Earth radiation	GERB						
Lightning mapper	MTG Lightning	LMS					

SUNSYNCHRONOUS	NOAA	DMSP	NPOESS	MetOp	Meteor-3M	FY-1 and FY-3
VIS/IR imager	AVHRR/3			AVHRR/3	MR-2000M, Klimat, MSU-MR	MVISR, VIRR
VIS/IR advanced imager			VIIRS	VIRI-M		MERSI
IR sounder	HIRS 3/4			HIRS/4		IRAS
IR advanced sounder			CrIS	IASI	IRFS-2	
MW imager		SSM/I			MIVZA	MWRI
MW imager/sounder		SSMIS	CMIS		MTVZA	
MW sounder (temperature)	AMSU-A	SSM/T		AMSU-A		MWTS
MW sounder (humidity)	AMSU-B, MHS	SSM/T2		MHS		MWHS
MW advanced sounder			ATMS	~ATMS		
Radio-occultation sounder			GPSOS	GRAS	Radiomet	
Altimeter			ALT			
Scatterometer				ASCAT		
Aerosol			APS		SAGE-III	
Earth radiation budget			ERBS			
Ozone	SBUS/2		OMPS	GOME-2	SFM-2	TOU/SBUS

Satellite operators to review the instrument sheets can be guided by Table 2 as follows:

- by <u>columns</u>, the satellite series is identified and the instrument sheets to be reviewed listed;
- by <u>rows</u>, instruments of the same type are identified, to pursue consistency of the templates.

Instrument sheets (in alphabetic order)

Yellow marks indicate either missing or uncertain/extrapolated information, to be filled or checked. However, for this first issue, all the information, even if not earmarked, must be checked.

ABI	**Advanced Baseline Imager**
Satellites	**GOES-R (to become GOES-16) and follow-on**
Status (end 2003)	**Being defined** – To be utilised from 2012 onward
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	16-channel VIS/IR radiometer
Coverage/cycle	Full disk each 15 min, 3000x5000 km^2 ("CONUS", Continental U.S.) in 5 min, 1000x1000 km^2 in 30 s
Resolution (s.s.p.)	0.5 km at 0.64 µm, 1.0 km at 0.47, 0.86 and 1.61 µm, 2 km in the remaining 12 channels

Central wavelength	Bandwidth	Radiometric accuracy
470 nm	40 nm	300 @ 100 % albedo
640 nm	100 nm	300 @ 100 % albedo
860 nm	40 nm	300 @ 100 % albedo
1380 nm	30 nm	300 @ 100 % albedo
1610 nm	60 nm	300 @ 100 % albedo
2260 nm	50 nm	300 @ 100 % albedo
3.90 µm	0.20 µm	0.1 K @ 300 K
6.15 µm	0.90 µm	0.1 K @ 300 K
7.00 µm	0.40 µm	0.1 K @ 300 K
7.40 µm	0.20 µm	0.1 K @ 300 K
8.50 µm	0.40 µm	0.1 K @ 300 K
9.70 µm	0.20 µm	0.1 K @ 300 K
10.3 µm	0.50 µm	0.1 K @ 300 K
11.2 µm	0.80 µm	0.1 K @ 300 K
12.3 µm	1.00 µm	0.1 K @ 300 K
13.3 µm	0.60 µm	0.3 K @ 300 K

ALT	**Radar Altimeter**
Satellites	**NPOESS 3 and 6**
Status (end 2003)	**Design being consolidated** – Utilisation period: 2013 to ~ 2026
Mission	Ocean topography, significant wave height, wind speed
Instrument type	Two-frequency (5.3 and 13.575 GHz) radar altimeter
Scanning technique	Nadir-only viewing, sampling at ...... km intervals along track
Coverage/cycle	22640 measurements/day at 25 km intervals – Global coverage (25 km average spacing) in 30 days
Resolution	25 km IFOV

AMSU-A	**Advanced Microwave Sounder Unit - A**
Satellites	**NOAA 15 to 19 - MetOp 1 and 2**
Status (end 2003)	**Operational** – Utilisation period: 1998 to ~ 2012 on NOAA, 2005 to ~ 2019 on MetOp
Mission	Temperature sounding in nearly-all-weather conditions
Instrument type	15-channel MW radiometer
Scanning technique	Cross-track: 30 steps of 48 km ssp, swath 2250 km - Along-track: one 48-km line each 8 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	48 km IFOV

Central frequency (GHz)	Bandwidth (MHz)	Polarisation	Accuracy
23.800	270	V	0.30 K
31.400	180	V	0.30 K
50.300	180	V	0.40 K
52.800	400	V	0.25 K
53.596 ± 0.115	170	H	0.25 K
54.400	400	H	0.25 K
54.940	400	V	0.25 K
55.500	330	H	0.25 K
f_0 = 57.290344	330	H	0.25 K
f_0 ± 0.217	78	H	0.40 K
f_0 ± 0.3222 ± 0.048	36	H	0.40 K
f_0 ± 0.3222 ± 0.022	16	H	0.60 K
f_0 ± 0.3222 ± 0.010	8	H	0.80 K
f_0 ± 0.3222 ± 0.0045	3	H	1.20 K
89.000	2000	V	0.50 K

AMSU-B	**Advanced Microwave Sounder Unit - B**
Satellites	**NOAA 15 to 19 - MetOp 1 and 2**
Status (end 2003)	**Operational** – Utilisation period: 1998 to ~ 2012 on NOAA, 2005 to ~ 2019 on MetOp
Mission	Humidity sounding in nearly-all-weather conditions. Also precipitation
Instrument type	5-channel MW radiometer
Scanning technique	Cross-track: 90 steps of 16 km ssp, swath 2250 km - Along-track: one 16-km line each 8/3 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	16 km IFOV

Central frequency (GHz)	Bandwidth (MHz)	Polarisation	Accuracy
89.0	1000	V	0.37 K
150.0	1000	V	0.84 K
183.31 ± 7.0	2000	V	0.60 K
183.31 ± 3.0	1000	V	0.70 K
183.31 ± 1.0	500	V	1.06 K

APS	**Aerosol Polarimetry Sensor**
Satellites	**NPOESS 1 and 4**
Status (end 2003)	**Being designed** – Utilisation period: 2009 to ~ 2022
Mission	Aerosol optical thickness, size distribution and shape
Instrument type	9-channel VIS/NIR/SWIR polarimeter with multi-angle capability
Scanning technique	Along-track viewing only, fore- and aft- ± 60° (... . steps of ..... °), one full measurement each ....km
Coverage/cycle	.... measurements/day at ..... km intervals – Global coverage (25 km average spacing) in 30 days
Resolution	10 km IFOV

Central wavelength	Bandwidth	Polarisations	Radiometric accuracy
412 nm	20 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
445 nm	18 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
488 nm	20 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
555 nm	20 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
672 nm	20 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
746 nm	15 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
865 nm	39 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
1240 nm	20 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
1378 nm	15 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
1610 nm	60 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
2250 nm	50 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo

ASCAT	**Advanced Scatterometer**
Satellites	**MetOp 1 to 3**
Status (end 2003)	**Being built** – Utilisation period: 2005 to ~ 2019
Mission	Sea surface wind vector. Also large-scale soil moisture
Instrument type	C-band radar scatterometer (5.255 GHz), side looking both left and right. 3 antennas on each side
Scanning technique	Two 500-km swaths separated by a 700-km gap along-track. 3 looks each pixel (45, 90 and 135° azimuth)
Coverage/cycle	Global coverage in 1.5 days
Resolution	Best quality: 50 km – standard quality: 25 km – basic sampling: 12.5 km

ATMS	**Advanced Technology Microwave Sounder**
Satellites	**NPP, NPOESS 1 to 6**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2026
Mission	Temperature and humidity sounding in nearly-all-weather conditions. Also precipitation
Instrument type	22-channel MW radiometer
Scanning technique	Cross-track: 96 steps of 16 km ssp, swath 2200 km - Along-track: one 16-km line each 8/3 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	16 km for channels 165-183 GHz, 32 km for channels 50-90 GHz, 75 km for channels 23-32 GHz

Central frequency (GHz)	Bandwidth (MHz)	Quasi-polarisation	Accuracy
23.800	270	QV	0.90 K
31.400	180	QV	0.90 K
50.300	180	QH	1.20 K
51.760	400	QH	0.75 K
52.800	400	QH	0.75 K
53.596 ± 0.115	170	QH	0.75 K
54.400	400	QH	0.75 K
54.940	400	QH	0.75 K
55.500	330	QH	0.75 K
$f_0 = 57.290344$	330	QH	0.75 K
$f_0 \pm 0.217$	78	QH	1.20 K
$f_0 \pm 0.3222 \pm 0.048$	36	QH	1.20 K
$f_0 \pm 0.3222 \pm 0.022$	16	QH	1.50 K
$f_0 \pm 0.3222 \pm 0.010$	8	QH	2.40 K
$f_0 \pm 0.3222 \pm 0.0045$	3	QH	3.60 K
89.5	5000	QV	0.50 K
165.5	3000	QH	0.60 K
183.31 ± 7.0	2000	QH	0.80 K
183.31 ± 4.5	2000	QH	0.80 K
183.31 ± 3.0	1000	QH	0.80 K
183.31 ± 1.8	1000	QH	0.80 K
183.31 ± 1.0	500	QH	0.90 K

AVHRR/3	**Advanced Very High Resolution Radiometer / 3**
Satellites	**TIROS-N, NOAA 6 to 19 - MetOp 1 and 2**
Status (end 2003)	**Operational** – Utilisation period: 1978 to ~ 2012 on NOAA, 2005 to ~ 2019 on MetOp
Mission	Multi-purpose VIS/IR imagery
Instrument type	6-channel VIS/IR radiometer (channel 1.6 and 3.7 alternative)
Scanning technique	Cross-track: 2048 pixel of 800 m ssp, swath 2900 km - Along-track: six 1.1-km lines/s
Coverage/cycle	Global coverage twice/day (IR) or once/day (VIS)
Resolution (s.s.p.)	1.1 km IFOV

Central wavelength	Spectral interval	Radiometric accuracy
0.630 µm	0.58 - 0.68 µm	9 @ 0.5 % albedo
0.862 µm	0.725 - 1.00 µm	9 @ 0.5 % albedo
1.61 µm	1.58 - 1.64 µm	20 @ 0.5 % albedo
3.74 µm	3.55 - 3.93 µm	0.12 K @ 300 K
10.80 µm	10.3 - 11.3 µm	0.12 K @ 300 K
12.00 µm	11.5 - 12.5 µm	0.12 K @ 300 K

CCD	**Charge-Coupled Device Camera**
Satellites	**INSAT-2E and INSAT-3A**
Status (end 2003)	**Operational** – Utilisation period: 1999 to ~ 2008
Mission	Cloud imagery
Instrument type	3-channel VIS camera
Coverage/cycle	Full disk each 3 hours. More frequently on demand. Daylight operation only
Resolution (s.s.p.)	1.0 km

Central wavelength	Spectral interval	Radiometric accuracy
0.71 µm	0.63 - 0.79 µm	.... @ ... % albedo
0.81 µm	0.77 – 0.86 µm	.... @ ... % albedo
1.62 µm	1.55 – 1.70 µm	.... @ ... % albedo

CMIS	**Conical-scanning Microwave Imager/Sounder**
Satellites	**NPOESS 1 to 6**
Status (end 2003)	**Design being consolidated** – Utilisation period: 2009 to ~ 2026
Mission	Multi-purpose MW imager with temperature/humidity sounding channels for improved precipitation
Instrument type	63-frequency, 77-channel MW radiometer
Scanning technique	Conical: 53.6- 58.1° zenith angle, swath 1700 km – Scan rate: 31.6 scan/min = 12.5 km/scan
Coverage/cycle	Global coverage once/day
Resolution (constant)	Changing with frequency, consistent with antenna diameters of 2.2 m (6-90 GHz) and 0.7 m (> 90GHz)

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy	IFOV	Pixel
6.625	350	V, H	.... K	34 x 56 km	40 x 12.5 km
10.65	100	V, H, R, L	.... K	21 x 35 km	20 x 12.5 km
18.7	200	V, H, P, M, L, R	.... K	12 x 20 km	10 x 12.5 km
23.8	400	V, H	.... K	9.5 x 17 km	10 x 12.5 km
36.5	1000	V, H, P, M	.... K	6.2 x 10 km	5 x 12.5 km
50.3	134	V	.... K	4.5 x 7.5 km	5 x 12.5 km
52.240	1280	V	.... K	4.5 x 7.5 km	5 x 12.5 km
53.570	960	V	.... K	4.5 x 7.5 km	5 x 12.5 km
54.380	440	V	.... K	4.5 x 7.5 km	5 x 12.5 km
54.905	350	V	.... K	4.5 x 7.5 km	5 x 12.5 km
55.490	340	V	.... K	4.5 x 7.5 km	5 x 12.5 km
56.660	300	V	.... K	4.5 x 7.5 km	5 x 12.5 km
59.380	280	V	.... K	4.5 x 7.5 km	5 x 12.5 km
59.940	440	V	.... K	4.5 x 7.5 km	5 x 12.5 km
60.3712	57.6	L	.... K	4.5 x 7.5 km	5 x 12.5 km
60.4080	16	L	.... K	4.5 x 7.5 km	5 x 12.5 km
60.4202	8.4	L	.... K	4.5 x 7.5 km	5 x 12.5 km
60.5088	44.8	L	.... K	4.5 x 7.5 km	5 x 12.5 km
60.43476 (**)	20 (40 FFT channels)	H	.... K	4.5 x 7.5 km	5 x 12.5 km
89.0	4000	V, H	.... K	2.5 x 4.2	2.5 x 6.25 km
166 ± 0.7875	1425	V	.... K	15 x 25	10 x 12.5 km
183.31 ± 7.70	4500	V	.... K	15 x 25	10 x 12.5 km
183.31 ± 3.10	3500	V	.... K	15 x 25	10 x 12.5 km
183.31 ± 0.7125	1275	V	.... K	15 x 25	10 x 12.5 km

(*) Polarisations: H = horizontal, V = vertical, P = + 45°, M = - 45°, L = left-hand circular, R = right-hand circular
(**) 20 MHz band centred on 60.43476 GHz (7+ line of O_2) split in 40 channels by Fast Fourier Transform (FFT)

CrIS	**Cross-track Infrared Sounder**
Satellites	**NPP, NPOESS 1 to 6**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2026
Mission	Temperature/humidity sounding, ozone profile and total-column green-house gases
Instrument type	IR spectrometer/interferometer (1302 channels)
Scanning technique	Cross-track: 32 steps of 48 km ssp, swath 2200 km - Along-track: one 48-km line each 8 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	3 x 3 14 km IFOV covering a 48 x 48 km² cell (average sampling distance: 16 km)

Spectral range (μm)	Spectral range (cm^{-1})	Spectral resolution (unapodised)	Accuracy
9.13 - 15.40 μm	650 - 1095 cm^{-1}	0.625 cm^{-1}	.... K @ ...... K
5.71 - 8.26 μm	1210 - 1750 cm^{-1}	1.25 cm^{-1}	.... K @ ...... K
3.92 – 4.64 μm	2155 - 2550 cm^{-1}	2.5 cm^{-1}	.... K @ ...... K

ERBS	**Earth Radiation Budget Sensor**
Satellites	**NPOESS 2 and 5**
Status (end 2003)	**Definition being consolidated** – Utilisation period: 2011 to ~ 2025
Mission	Earth radiation budget
Instrument type	Two broad-band and one narrow-band channel radiometer
Scanning technique	Cross-track: 80 steps of 20 km ssp, swath 3000 km - Along-track: one 20-km line each 3 s
Coverage/cycle	Global coverage twice/day (IR and total radiance) or once/day (short-wave)
Resolution (s.s.p.)	20 km

Channel	Spectral interval	Radiometric accuracy	Calibration accuracy	SNR
Narrow-band	8 - 12 μm	.... $Wm^{-2}sr^{-1}$	.... $Wm^{-2}sr^{-1}$	....
Short-wave	0.3 - 5.0 μm	.... $Wm^{-2}sr^{-1}$	.... $Wm^{-2}sr^{-1}$	....
Total radiance	0.3 - 100 μm	.... $Wm^{-2}sr^{-1}$	.... $Wm^{-2}sr^{-1}$	....

GERB	**Geostationary Earth Radiation Budget**
Satellites	**Meteosat 8 to 11 (Meteosat Second Generation)**
Status (end 2003)	**Commissioned** – Utilisation period: 2002 to ~ 2018
Mission	Earth radiation budget
Instrument type	Two broad-band channels radiometer
Coverage/cycle	Full disk each 5 min. Integration over three cycles (15 min) to comply with accuracy requirements
Resolution (s.s.p.)	42 km

Channel	Spectral interval	Radiometric accuracy	Calibration accuracy	SNR
Short-wave	0.32 - 4.0 μm	0.8 $Wm^{-2}sr^{-1}$	2.4 $Wm^{-2}sr^{-1}$	1250
Total radiance	0.32 - 30 μm	0.15 $Wm^{-2}sr^{-1}$	0.4 $Wm^{-2}sr^{-1}$	400

GOME-2	**Global Ozone Monitoring Experiment - 2**
Satellites	**MetOp 1 to 3**
Status (end 2003)	**Being built** – Utilisation period: 2005 to ~ 2019
Mission	Ozone profile and total-column or profile of other species
Instrument type	UV/VIS grating spectrometer, four bands, 4096 channels, with 200 polarisation channels
Scanning technique	Cross-track: 24 steps of 40 km or 80 km ssp, swath 960 or 1920 km - Along-track: one 40-km line each 6 s
Coverage/cycle	Global coverage each 3 days with high resolution or 1.5 days with low resolution. Daylight only
Resolution (s.s.p.)	40 x 40 km² associated to 960 km swath or 40 x 80 km² associated to 1920 km swath

Spectral range	Number of channels	Spectral resolution	SNR at specified input radiance
240 - 315 nm	1024	0.24 - 0.29 nm	....
311 - 403 nm	1024	0.26 - 0.28 nm	....
401 - 600 nm	1024	0.44 - 0.53 nm	....
590 - 790 nm	1024	0.44 - 0.53 nm	....
312 - 790 nm	200	2.8 nm at 312 nm to 40 nm at 790 nm	....

GPSOS	**Global Positioning System Occultation Sensor**
Satellites	**NPOESS 2 and 5**
Status (end 2003)	**Design being consolidated** – Utilisation period: 2011 to ~ 2025
Mission	Temperature/humidity sounding with highest vertical resolution, space weather
Instrument type	GPS receiver measuring the phase delay due to refraction during occultation between GPS and LEO
Scanning technique	Limb scanning from 830 km to close-to-surface by time sampling – Azimuth 90° fore- and aft-
Coverage/cycle	About 500 soundings/day – Average spacing 1000 km – Global coverage (300 km spacing) in 10 days
Resolution	About 300 km

GRAS	**GNSS Receiver for Atmospheric Sounding**
Satellites	**MetOp 1 to 3**
Status (end 2003)	**Being built** – Utilisation period: 2005 to ~ 2019
Mission	Temperature/humidity sounding with highest vertical resolution, space weather
Instrument type	GPS receiver measuring the phase delay due to refraction during occultation between GPS and LEO
Scanning technique	Limb scanning from 830 km to close-to-surface by time sampling – Azimuth 90° fore- and aft-
Coverage/cycle	About 500 soundings/day – Average spacing 1000 km – Global coverage (300 km spacing) in 10 days
Resolution	About 300 km

HES	**Hyperspectral Environmental Suite**
Satellites	**GOES-R (to become GOES-16) and follow-on**
Status (end 2003)	**Being defined** – To be utilised from 2012 onward
Mission	Temperature/humidity sounding and wind profile derivation by tracking water vapour features
Instrument type	IR spectrometer (+ one VIS channel) for sounding, 14-19 channel radiometer for coastal waters
Coverage/cycle	Full disk in maximum 60 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	2-10 km for sounding (0.5-1.0 km for the VIS channel), 0.15-2.0 km for coastal waters

Spectral range (μm)	**Spectral range (cm^{-1})**	**Spectral resolution** (goal and threshold)	**Accuracy** (variation in the range)
15.0 - 15.4 μm	650 - 665 cm^{-1}	0.5 - 0.625 cm^{-1}	0.30 - 1.00 K @ 250 K
13.9 - 15.0 μm	665 - 720 cm^{-1}	0.5 - 0.625 cm^{-1}	0.17 - 0.30 K @ 250 K
13.0 - 13.9 μm	720 - 770 cm^{-1}	0.5 - 0.625 cm^{-1}	0.15 - 0.17 K @ 250 K
9.84 - 13.0 μm	770 - 1016 cm^{-1}	0.5 - 0.625 cm^{-1}	0.15 - 0.20 K @ 250 K
9.56 - 9.84 μm	1016 - 1046 cm^{-1}	0.5 - 0.625 cm^{-1}	0.15 - 0.20 K @ 250 K
8.33 – 9.56 μm	1046 - 1200 cm^{-1}	0.5 - 0.625 cm^{-1}	0.20 - 0.90 K @ 250 K
5.75 - 8.26 μm **or**	1210 - 1740 cm^{-1} **or**	0.625 - 1.25 cm^{-1}	0.13 - 0.24 K @ 250 K
4.65 - 6.06 μm	1650 - 2150 cm^{-1}	0.625 - 1.25 cm^{-1}	0.60 - 1.60 K @ 250 K
4.44 - 4.65 μm	2150 - 2250 cm^{-1}	2.5 cm^{-1}	1.5 - 2.0 K @ 250 K
3.68 - 4.44 μm (**goal**)	2250 - 2720 cm^{-1}	2.5 cm^{-1}	0.4 - 3.0 K @ 250 K
0.52 - 0.70 μm	N/A	0.18 μm	300 @ 100 % albedo

			Central wavelength	Bandwidth	SNR at specified input radiance
Channel designed for coastal water monitoring	Baseline channels for ocean colour Resolution 150 - 300 m		0.412 μm	0.02 μm	300 (threshold) to 600 (goal)
			0.443 μm	0.02 μm	300 (threshold) to 600 (goal)
			0.477 μm	0.02 μm	300 (threshold) to 600 (goal)
			0.490 μm	0.02 μm	300 (threshold) to 600 (goal)
			0.510 μm	0.02 μm	300 (threshold) to 600 (goal)
			0.530 μm	0.02 μm	300 (threshold) to 600 (goal)
			0.550 μm	0.02 μm	300 (threshold) to 600 (goal)
			0.645 μm	0.02 μm	300 (threshold) to 600 (goal)
			0.667 μm	0.02 μm	300 (threshold) to 600 (goal)
			0.678 μm	0.02 μm	300 (threshold) to 600 (goal)
			0.750 μm	0.02 μm	300 (threshold) to 600 (goal)
			0.763 μm	0.02 μm	300 (threshold) to 600 (goal)
			0.865 μm	0.04 μm	300 (threshold) to 600 (goal)
			0.905 μm	0.02 μm	300 (threshold) to 600 (goal)
	Goal channels	Cloud detection Resolution 0.9 - 1.2 km	1.38 μm	0.03 μm	300 (threshold) to 600 (goal)
			1.61 μm	0.06 μm	300 (threshold) to 600 (goal)
			2.26 μm	0.05 μm	300 (threshold) to 600 (goal)
		Sea surface temperature Resolution 1.0 - 2.0 km	11.2 μm	0.8 μm	NEΔT = 0.1 K @ 250 K
			12.3 μm	1.0 μm	NEΔT = 0.1 K @ 250 K

HIRS 3/4	**High-resolution Infra Red Sounder 3 / 4**
Satellites	**TIROS-N, NOAA 6 to 19 - MetOp 1 and 2**
Status (end 2003)	**Operational** – Utilisation period: 1978 to ~ 2012 on NOAA, 2005 to ~ 2019 on MetOp
Mission	Temperature/humidity sounding
Instrument type	20-channel IR radiometer (including one VIS)
Scanning technique	Cross-track: 56 steps of 26 km ssp, swath 2250 km - Along-track: one line each 42 km each 6.4 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	18 km for HIRS/3, 10 km IFOV for HIRS/4

Wavelength	Wavenumber	Bandwidth	Radiometric accuracy
14.95 μm	669 cm^{-1}	3 cm^{-1}	..... K @ ..... K
14.71 μm	680 cm^{-1}	10 cm^{-1}	..... K @ ..... K
14.49 μm	690 cm^{-1}	12 cm^{-1}	..... K @ ..... K
14.22 μm	703 cm^{-1}	16 cm^{-1}	..... K @ ..... K
13.97 μm	716 cm^{-1}	16 cm^{-1}	..... K @ ..... K
13.64 μm	733 cm^{-1}	16 cm^{-1}	..... K @ ..... K
13.35 μm	749 cm^{-1}	16 cm^{-1}	..... K @ ..... K
12.47 μm	802 cm^{-1}	16 cm^{-1}	..... K @ ..... K
11.11 μm	900 cm^{-1}	35 cm^{-1}	..... K @ ..... K
9.71 μm	1030 cm^{-1}	25 cm^{-1}	..... K @ ..... K
7.33 μm	1364 cm^{-1}	40 cm^{-1}	..... K @ ..... K
6.52 μm	1534 cm^{-1}	55 cm^{-1}	..... K @ ..... K
4.57 μm	2188 cm^{-1}	23 cm^{-1}	..... K @ ..... K
4.52 μm	2210 cm^{-1}	23 cm^{-1}	..... K @ ..... K
4.47 μm	2237 cm^{-1}	23 cm^{-1}	..... K @ ..... K
4.45 μm	2247 cm^{-1}	23 cm^{-1}	..... K @ ..... K
4.13 μm	2420 cm^{-1}	28 cm^{-1}	..... K @ ..... K
4.00 μm	2500 cm^{-1}	35 cm^{-1}	..... K @ ..... K
3.76 μm	2660 cm^{-1}	100 cm^{-1}	..... K @ ..... K
0.69 μm	N/A	0.05 μm	.... @ .... % albedo

IASI	**Infrared Atmospheric Sounding Interferometer**
Satellites	**MetOp 1 to 3**
Status (end 2003)	**Being built** – Utilisation period: 2005 to ~ 2019
Mission	Temperature/humidity sounding, ozone profile and total-column green-house gases
Instrument type	IR spectrometer/interferometer (8460 channels) with one embedded IR imaging channel
Scanning technique	Cross-track: 30 steps of 48 km ssp, swath 2050 km - Along-track: one 48-km line each 8 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	2 x 2 12 km IFOV close to the centre of a 48 x 48 km^2 cell (average sampling distance: 24 km)

Spectral range (μm)	**Spectral range (cm^{-1})**	**Spectral resolution (unapodised)**	**Accuracy (for 0.5 cm^{-1} channels)**
8.26 - 15.50 μm	645 - 1210 cm^{-1}	0.25 cm^{-1}	0.2-0.3 K @ 280 K
5.00 - 8.26 μm	1210 - 2000 cm^{-1}	0.25 cm^{-1}	0.2-0.5 K @ 280 K
3.62 - 5.00 μm	2000 - 2760 cm^{-1}	0.25 cm^{-1}	0.5-2.0 K @ 280 K
3.7 - 4.0 μm	N/A	N/A	.... K @ 300 K

IMAGER	**GOES Imager**
Satellites	**GOES 8 to 15**
Status (end 2003)	**Operational** – Utilisation period: 1994 to ~ 2015
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	5-channel VIS/IR radiometer
Coverage/cycle	Full disk each 30 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	4.0 km for IR channels; 1.0 km for the VIS channel

Central wavelength	**Spectral interval**	**Radiometric accuracy**
0.65 μm	0.55 - 0.75 μm	.... @ ... % albedo
3.90 μm	3.80 - 4.00 μm	0.11 K @ 300 K
6.55 μm	5.80 - 7.30 μm	0.14 K @ 300 K
10.70 μm	10.2 - 11.2 μm	0.09 K @ 300 K
13.35 μm	13.0 - 13.7 μm	...... K @ 300 K

IMAGER	**INSAT Imager**
Satellites	**INSAT-3D**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2010
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	6-channel VIS/IR radiometer
Coverage/cycle	Full disk each ...... min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	4.0 km for IR window channels; 1.0 km for VIS/NIR channels; 8.0 km for water-vapour channel

Central wavelength	**Spectral interval**	**Radiometric accuracy**
0.62 μm	0.52 - 0.72 μm	.... @ ... % albedo
1.62 μm	1.55 – 1.70 μm	.... @ ... % albedo
3.90 μm	3.80 - 4.00 μm	...... K @ 300 K
6.75 μm	6.50 - 7.00 μm	...... K @ ..... K
10.7 μm	10.2 - 11.2 μm	...... K @ 300 K
12.0 μm	11.5 – 12.5 μm	...... K @ 300 K

IRAS	**Infra Red Atmospheric Sounder**
Satellites	**FY-3 A to G**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2021
Mission	Temperature/humidity sounding
Instrument type	26-channel IR radiometer (including one VIS)
Scanning technique	Cross-track: 56 steps of 26 km ssp, swath 2250 km - Along-track: one line each 42 km each 6.4 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	17 km IFOV

Wavelength	Wavenumber	Bandwidth	Radiometric accuracy
14.95 µm	669 cm^{-1}	3 cm^{-1}	..... K @ ..... K
14.80 µm	676 cm^{-1}	3 cm^{-1}	..... K @ ..... K
14.71 µm	680 cm^{-1}	10 cm^{-1}	..... K @ ..... K
14.49 µm	690 cm^{-1}	12 cm^{-1}	..... K @ ..... K
14.22 µm	703 cm^{-1}	16 cm^{-1}	..... K @ ..... K
13.97 µm	716 cm^{-1}	16 cm^{-1}	..... K @ ..... K
13.64 µm	733 cm^{-1}	16 cm^{-1}	..... K @ ..... K
13.35 µm	749 cm^{-1}	16 cm^{-1}	..... K @ ..... K
11.11 µm	900 cm^{-1}	35 cm^{-1}	..... K @ ..... K
9.71 µm	1030 cm^{-1}	25 cm^{-1}	..... K @ ..... K
8.16 µm	1225 cm^{-1}	25 cm^{-1}	..... K @ ..... K
7.33 µm	1364 cm^{-1}	40 cm^{-1}	..... K @ ..... K
6.52 µm	1534 cm^{-1}	80 cm^{-1}	..... K @ ..... K
4.57 µm	2188 cm^{-1}	23 cm^{-1}	..... K @ ..... K
4.52 µm	2210 cm^{-1}	23 cm^{-1}	..... K @ ..... K
4.47 µm	2237 cm^{-1}	23 cm^{-1}	..... K @ ..... K
4.40 µm	2273 cm^{-1}	23 cm^{-1}	..... K @ ..... K
4.20 µm	2381 cm^{-1}	23 cm^{-1}	..... K @ ..... K
4.00 µm	2500 cm^{-1}	35 cm^{-1}	..... K @ ..... K
3.76 µm	2660 cm^{-1}	100 cm^{-1}	..... K @ ..... K
1.64 µm	N/A	TBD	.... @ .... % albedo
1.24 µm	N/A	TBD	.... @ .... % albedo
0.94 µm	N/A	TBD	.... @ .... % albedo
0.885 µm	N/A	TBD	.... @ .... % albedo
0.69 µm	N/A	0.05 µm	.... @ .... % albedo
0.659 µm	N/A	TBD	.... @ .... % albedo

IRFS-2	**Infrared Sounding Spectrometer**
Satellites	**Meteor-3M N2 and N3**
Status (end 2003)	**Being built** – Utilisation period: 2005 to ~ 2012
Mission	Temperature/humidity sounding, ozone profile and total-column green-house gases
Instrument type	IR spectrometer/interferometer (~ 4000 channels)
Scanning technique	Cross-track: 16 steps of 100 km ssp, swath 2000 km - Along-track: one line each 100 km each 16 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	35 km IFOV

Spectral range (µm)	Spectral range (cm^{-1})	Spectral resolution (unapodised)	Accuracy
5 - 15 µm	665 - 2000 cm^{-1}	0.3 cm^{-1}	.... K @ ...... K
.... - .... µm	.... - .... cm^{-1}	0.3 cm^{-1}	.... K @ ...... K
.... - .... µm	.... - .... cm^{-1}	0.3 cm^{-1}	.... K @ ...... K

JAMI	**Japanese Advanced Meteorological Imager**
Satellites	**MTSAT 1 and 2**
Status (end 2003)	**Close to be launched** – Utilisation period: 2004 to ~ 2014
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	5-channel VIS/IR radiometer
Coverage/cycle	Full disk each 60 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	4.0 km for IR channels; 1.0 km for the VIS channel

Central wavelength	Spectral interval	Radiometric accuracy
0.72 µm	0.55 - 0.90 µm	.... @ .... % albedo
3.75 µm	3.50 - 4.00 µm	.... K @ 300 K
6.75 µm	6.50 - 7.00 µm	.... K @ ...... K
10.8 µm	10.3 - 11.3 µm	.... K @ 300 K
12.0 µm	11.5 - 12.5 µm	...... K @ 300 K

Klimat	**Infrared Imaging Radiometer**
Satellites	**Meteor-3 N1 to N7, Meteor-3M N1**
Status (end 2003)	**Operational** – Utilisation period: 1985 to ~ 2005
Mission	Cloud imagery
Instrument type	1-channel IR radiometer
Scanning technique	Cross-track: .... pixel of 3.0 km ssp, swath 3100 km - Along-track: two 3-km lines/s
Coverage/cycle	Global coverage twice/day
Resolution (s.s.p.)	3.0 km IFOV

Central wavelength	Spectral interval	Radiometric accuracy
11,5 µm	10.5 – 12.5 µm	...... K @ 300 K

LMS	**Lightning Mapper Sensor**
Satellites	**GOES-R and follow-on**
Status (end 2003)	**Proposed** – To be utilised from 2012 onward
Mission	Proxy for convective precipitation, proxy for NO_x generation, study of Earth electric field
Instrument type	CCD camera operating at 777.4 nm (O_2) to count flashes and measure their intensity
Coverage/cycle	Large fraction of the disk continuously observed (time resolution 2 ms)
Resolution (s.s.p.)	8 km

MERSI	**Medium Resolution Spectral Imager**
Satellites	**FY-3 A to G**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2021
Mission	Vegetation indexes and ocean colour
Instrument type	20-channel radiometer, 19 narrow-bandwidth in VIR/NIR/SWIR and one broadband in the Thermal IR
Scanning technique	Cross-track: .... pixel of .... km ssp, swath .... km - Along-track: ....-km lines/s
Coverage/cycle	Global coverage in ....../day (in daylight)
Resolution (s.s.p.)	250 m for broad-band channels, 1.0 km for narrow-band channels

Channel set	Central wavelength	Spectral range or Bandwidth	Radiometric accuracy
Broad-band channels with 250 m resolution, mostly for clouds, vegetation and surface temperature	0.470 µm	0.445 - 0.495 µm	.... @ .... % albedo
	0.550 µm	0.525 - 0.575 µm	.... @ .... % albedo
	0.650 µm	0.625 - 0.675 µm	.... @ .... % albedo
	0.865 µm	0.840 - 0.890 µm	.... @ .... % albedo
	11.250 µm	10.0 - 12.5 µm	.... K @ 300 K
Narrow-band channels with 1000 m resolution, for ocean colour, vegetation, aerosol	412 nm	20 nm	.... @ .... % albedo
	443 nm	20 nm	.... @ .... % albedo
	490 nm	20 nm	.... @ .... % albedo
	520 nm	20 nm	.... @ .... % albedo
	565 nm	20 nm	.... @ .... % albedo
	650 nm	20 nm	.... @ .... % albedo
	685 nm	20 nm	.... @ .... % albedo
	765 nm	20 nm	.... @ .... % albedo
	865 nm	20 nm	.... @ .... % albedo
	905 nm	20 nm	.... @ .... % albedo
	940 nm	20 nm	.... @ .... % albedo
	980 nm	20 nm	.... @ .... % albedo
	1030 nm	20 nm	.... @ .... % albedo
	1640 nm	50 nm	.... @ .... % albedo
	2130 nm	50 nm	.... @ .... % albedo

MHS	**Microwave Humidity Sounder Unit**
Satellites	**NOAA 18 to 19 - MetOp 1 to 3**
Status (end 2003)	**Close to launch** – Utilisation period: 2004 to ~ 2012 on NOAA, 2005 to ~ 2019 on MetOp
Mission	Humidity sounding in nearly-all-weather conditions. Also precipitation
Instrument type	5-channel MW radiometer
Scanning technique	Cross-track: 90 steps of 16 km ssp, swath 2250 km - Along-track: one 16-km line each 8/3 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	16 km IFOV

Central frequency (GHz)	Bandwidth (MHz)	Polarisation	Accuracy
89.0	2800	V	1.0 K
157.0	2800	V	1.0 K
183.31 ± 3.0	2000	V	1.0 K
183.31 ± 1.0	1000	V	1.0 K
190.311	2200	V	1.0 K

MIVZA	**Imaging Microwave Radiometer**
Satellites	**Meteor-3M N1**
Status (end 2003)	**Operational** – Utilisation period: 2001 to ~ 2005
Mission	Multi-purpose MW imager
Instrument type	3-frequency, 5-channel MW radiometer
Scanning technique	Conical: 53.1° zenith angle, swath 1500 km – Scan rate: .... scan/min = ... km/scan
Coverage/cycle	Global coverage once/day
Resolution (constant)	Changing with frequency, consistent with an antenna diameter of ..... x .... cm

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy	IFOV	Pixel
20.0	....		.... K	..... x ..... km	...... x ...... km
35.0	....	V, H	.... K	..... x ..... km	...... x ...... km
94.0	....	V, H	.... K	..... x ..... km	...... x ...... km

MR-2000M	**Television Camera**
Satellites	**Meteor-3 N1 to N7, Meteor-3M N1**
Status (end 2003)	**Operational** – Utilisation period: 1985 to ~ 2005
Mission	Cloud imagery
Instrument type	1-channel television camera
Scanning technique	Cross-track: .... pixel of .... km ssp, swath 3100 km - Along-track: ....-km lines/s
Coverage/cycle	Global coverage once/day (in daylight)
Resolution (s.s.p.)	1.0 km

Central wavelength	Spectral interval	Radiometric accuracy
0.65 µm	0.50 - 0.80 µm	.... @ ..... % albedo

MSU-G	**GOMS Imager**
Satellites	**GOMS-N2 and follow on**
Status (end 2003)	**Planned** – To be utilised from 2006 onward
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	12-channel VIS/IR radiometer
Coverage/cycle	Full disk each 30 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	4.0 km for the IR channels, 1.0 km for the VIS/NIR channels

Central wavelength	Spectral interval	Radiometric accuracy
0.57 µm	0.50 - 0.65 µm	10 @ ...... % albedo
0.72 µm	0.65 - 0.80 µm	10 @ ...... % albedo
0.86 µm	0.80 - 0.90 µm	7 @ .... % albedo
~ 1.6 µm (TBC)	TBD	3 @ .... % albedo
3.75 µm	3.50 - 4.00 µm	0.35 K @ 300 K
6.35 µm	5.70 - 7.00 µm	0.75 K @ ..... K
8.00 µm	7.50 - 8.50 µm	0.28 K @ 300 K
8.70 µm	8.20 - 9.20 µm	0.28 K @ 300 K
9.70 µm	9.20 - 10.2 µm	1.5 K @ ..... K
10.7 µm	10.2 - 11.2 µm	0.3 K @ 300 K
11.7 µm	11.2 - 12.5 µm	0.3 K @ 300 K
~ 13.4 µm (TBC)	TBD	1.8 K @ ...... K

MSU-MR	**VIS/IR Imaging Radiometer**
Satellites	**Meteor-3M N2 and N3**
Status (end 2003)	**Being built** – Utilisation period: 2005 to ~ 2012
Mission	Multi-purpose VIS/IR imagery
Instrument type	6-channel VIS/IR radiometer
Scanning technique	Cross-track: 2048 pixel of 800 m ssp, swath 3000 km - Along-track: six 1.1-km lines/s
Coverage/cycle	Global coverage twice/day (IR) or once/day (VIS)
Resolution (s.s.p.)	1.0 km IFOV

Central wavelength	Spectral interval	Radiometric accuracy
0.60 µm	0.50 - 0.70 µm	.... @ ..... % albedo
0.95 µm	0.80 - 1.10 µm	.... @ ..... % albedo
1.70 µm	1.60 - 1.80 µm	.... @ ..... % albedo
3.80 µm	3.50 – 4.10 µm	.... K @ 300 K
11.00 µm	10.5 - 11.5 µm	.... K @ 300 K
12.00 µm	11.5 - 12.5 µm	.... K @ 300 K

MTG imager(s)	**Name(s) to be defined**
Satellites	**Meteosat-12 and follow-on (Meteosat Third Generation)**
Status (end 2003)	**Being defined** – To be utilised from 2015 onward
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	Imager-1: ~ 5-channel VIS/IR radiometer; Imager-2: ~ 15-channel VIS/IR radiometer
Coverage/cycle	Imager-1: !/3 of the disk in 2-5 min; Imager-2: full disk in 5-15 min
Resolution (s.s.p.)	Imager-1: 0.5-1.0 km; Imager-2: 1.0-3.0 km

Imager-1			**Imager-2**		
Central wavelength	**Bandwidth**	**Accuracy**	**Central wavelength**	**Bandwidth**	**Accuracy**
			0.443 μm	0.02 μm	10 @ 1 % albedo
0.60 μm	0.20 μm	10 @ 1 % albedo	0.645 μm	0.05 μm	10 @ 1 % albedo
			0.865 μm	0.04 μm	10 @ 1 % albedo
			1.375 μm	0.03 μm	10 @ 1 % albedo
			1.61 μm	0.06 μm	10 @ 1 % albedo
2.20 μm	0.20 μm	10 @ 1 % albedo	2.13 μm	0.05 μm	10 @ 1 % albedo
3.80 μm	0.60 μm	0.2 K @ 300 K	3.80 μm	0.60 μm	0.1 K @ 300 K
			6.70 μm	0.40 μm	0.3 K @ 250 K
7.35 μm	0.70 μm	0.5 K @ 250 K	7.35 μm	0.30 μm	0.3 K @ 250 K
			8.55 μm	0.30 μm	0.1 K @ 300 K
			9.70 μm	0.30 μm	0.3 K @ 250 K
11.4 μm	2.20 μm	0.2 K @ 300 K	10.8 μm	1.0 μm	0.1 K @ 300 K
			12.0 μm	1.0 μm	0.1 K @ 300 K
			13.4 μm	0.3 μm	0.2 K @ 270 K
			14.0 μm	0.3 μm	0.2 K @ 250 K

	λ [nm]	**Δλ [nm]**	**Accuracy**
Option 1 for Imager-2 (A-band of O_2) for improved cloud-top height	755	5	150 @ 100 $Wm^{-2}sr^{-1}\mu m^{-1}$
	761	3	150 @ 100 $Wm^{-2}sr^{-1}\mu m^{-1}$
	764	6	150 @ 100 $Wm^{-2}sr^{-1}\mu m^{-1}$
	775	5	150 @ 100 $Wm^{-2}sr^{-1}\mu m^{-1}$
	Spectral range	**Spectral resolution**	**Accuracy**
Option 2 for Imager-2 (spectrometer in the 5 μm band) for temperature/humidity sounding in the lower troposphere	4.33-5.49 μm	$\Delta\nu$ = 2 cm^{-1} (256 channels)	0.2 K @ 280 K
	λ [μm]	**Δλ [nm]**	**Accuracy**
Option 3 for Imager-2 (slicing of the 14 μm band) for improved cloud top height	13.4775	45-91	0.2-1.0 K @ 270 K
	13.6985	47-94	0.2-1.0 K @ 250 K
	13.9860	98-293	0.2-1.0 K @ 250 K
	14.0350	98-295	0.2-0.6 K @ 250 K
	14.1340	100-300	0.2-0.6 K @ 250 K
	14.1840	101-302	0.2-0.6 K @ 250 K
	14.3360	103-308	0.2-0.7 K @ 230 K
	14.4930	105-315	0.2-0.7 K @ 230 K
	14.5990	107-320	0.2-0.7 K @ 230 K

MTG lightning mapper	**Name to be defined**
Satellites	**Meteosat-12 and follow-on (Meteosat Third Generation)**
Status (end 2003)	**Being defined** – To be utilised from 2015 onward
Mission	Proxy for convective precipitation, proxy for NO_x generation, study of Earth electric field
Instrument type	CCD camera operating at 777.4 nm (O_2) to count flashes and measure their intensity
Coverage/cycle	Large fraction of the disk continuously observed (time resolution 1-2 ms)
Resolution (s.s.p.)	5-10 km

MTG sounder	**Name to be defined**
Satellites	**Meteosat-12 and follow-on (Meteosat Third Generation)**
Status (end 2003)	**Being defined** – To be utilised from 2015 onward
Mission	Temperature/humidity sounding and wind profile derivation by tracking water vapour features
Instrument type	IR spectrometer/interferometer with large detector arrays for simultaneous sounding of more pixels
Coverage/cycle	Full disk in 15-60 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	3-6 km (at 5 µm), 6-12 km (at 14 µm)

Spectral range (µm)	**Spectral range (cm^{-1})**	**Spectral resolution** (goal and threshold)	**Accuracy** (goal and threshold)
14.3 - 15.0 µm	667 - 700 cm^{-1}	0.5 - 0.625 cm^{-1}	Not specified
13.0 - 14.3 µm	700 - 770 cm^{-1}	0.5 - 0.625 cm^{-1}	0.10 - 0.20 K @ 280 K
10.0 - 13.0 µm	770 - 1000 cm^{-1}	0.5 - 0.625 cm^{-1}	0.12 - 0.24 K @ 280 K
9.35 - 10.0 µm	1000 - 1070 cm^{-1}	0.5 - 1.25 cm^{-1}	0.15 - 0.20 K @ 280 K
8.26 - 9.35 µm	1070 - 1210 cm^{-1}	0.5 - 1.25 cm^{-1}	0.20 - 0.30 K @ 280 K
6.25 - 8.26 µm	1210 - 1600 cm^{-1}	0.5 - 1.25 cm^{-1}	0.10 - 0.20 K @ 280 K
5.00 - 6.25 µm	1600 - 2000 cm^{-1}	0.5 - 1.25 cm^{-1}	0.25 - 0.35 K @ 280 K
4.44 - 5.00 µm	2000 - 2250 cm^{-1}	0.5 - 1.25 cm^{-1}	0.15 - 0.20 K @ 280 K
4.17 - 4.44 µm	2250 - 2400 cm^{-1}	0.5 - 1.25 cm^{-1}	0.25 - 0.30 K @ 280 K
4.00 - 4.17 µm	2400 - 2500 cm^{-1}	0.5 - 1.25 cm^{-1}	0.25 - 0.40 K @ 280 K

MTVZA	**Imaging/Sounding Microwave Radiometer**
Satellites	**Meteor-3M N1, N2 and N3**
Status (end 2003)	**Operational** – Utilisation period: 2001 to ~ 2009
Mission	Multi-purpose MW imager with temperature/humidity sounding channels for improved precipitation
Instrument type	20-frequency, 26-channel MW radiometer
Scanning technique	Conical: 69° zenith angle, swath 2200 km – Scan rate: 24.9 scan/min = 15.8 km/scan
Coverage/cycle	Near-global coverage twice/day
Resolution (constant)	Changing with frequency, consistent with an antenna diameter of ...... x .... cm

Central frequency (GHz)	**Bandwidth (MHz)**	**Polarisations**	**Accuracy**	**IFOV**	**Pixel**
18.7	800	V, H	0.25 K	75 x 136 km	35.6 x 31.6 km
22.235	1600	V	0.25 K	68 x 124 km	35.6 x 31.6 km
33.0	2000	V, H	0.35 K	45 x 82 km	35.6 x 31.6 km
36.5	2000	V, H	0.38 K	41 x 75 km	35.6 x 31.6 km
42.0	2000	V, H	0.45 K	36 x 65 km	35.6 x 31.6 km
48.0	2000	V, H	0.45 K	32 x 58 km	35.6 x 31.6 km
52.80	400	V	0.3 K	30 x 55 km	71.2 x 63.2 km
53.30	400	V	0.3 K	30 x 55 km	71.2 x 63.2 km
53.80	400	V	0.3 K	30 x 55 km	71.2 x 63.2 km
54.64	400	V	0.3 K	30 x 55 km	71.2 x 63.2 km
55.63	400	V	0.3 K	30 x 55 km	71.2 x 63.2 km
57.290344±0.3222±0.1	50	H	0.3 K	30 x 55 km	71.2 x 63.2 km
57.290344±0.3222±0.05	20	H	0.3 K	30 x 55 km	71.2 x 63.2 km
57.290344±0.3222±0.025	10	H	0.3 K	30 x 55 km	71.2 x 63.2 km
57.290344±0.3222±0.01	5	H	0.3 K	30 x 55 km	71.2 x 63.2 km
57.290344±0.3222±0.005	3	H	0.3 K	30 x 55 km	71.2 x 63.2 km
91.65	3000	V, H	0.5 K	18 x 33 km	17.8 x 15.8 km
183.31 ± 7.0	1500	V	0.4 K	12 x 22 km	71.2 x 63.2 km
183.31 ± 3.0	1000	V	0.4 K	12 x 22 km	71.2 x 63.2 km
183.31 ± 1.0	500	V	0.4 K	12 x 22 km	71.2 x 63.2 km

MVIRI	Meteosat Visible Infra-Red Imager
Satellites	**Meteosat 1 to 7**
Status (end 2003)	**Operational** – utilisation period: 1977 to ~ 2005
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	3-channel VIS/IR radiometer
Coverage/cycle	Full disk each 30 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	5.0 km for IR channels; 2.5 km for the VIS channel

Central wavelength	Spectral interval	Radiometric accuracy
0.70 μm	0.50 - 0.90 μm	3 @ 1% albedo
6.40 μm	5.70 - 7.10 μm	1.0 K @ 250 K
11.5 μm	10.5 - 12.5 μm	0.5 K @ 300 K

MVISR	Multichannel Visible Infrared Scanning Radiometer
Satellites	**FY-1 A to D**
Status (end 2003)	**Operational** – Utilisation period: 1988 to ~ 2006
Mission	Multi-purpose VIS/IR imagery with emphasis on vegetation and ocean colour
Instrument type	10-channel VIS/IR radiometer
Scanning technique	Cross-track: 2048 pixel of 800 m ssp, swath 2800 km - Along-track: six 1.1-km lines/s
Coverage/cycle	Global coverage twice/day (IR) or once/day (VIS)
Resolution (s.s.p.)	1.1 km

Central wavelength	Spectral interval	Radiometric accuracy
0.455 μm	0.43 - 0.48 μm	3.0. @ 0.5 % albedo
0.505 μm	0.48 - 0.53 μm	3.0. @ 0.5 % albedo
0.555 μm	0.53 - 0.58 μm	3.0. @ 0.5 % albedo
0.630 μm	0.58 - 0.68 μm	3.0. @ 0.5 % albedo
0.865 μm	0.84 - 0.89 μm	3.0. @ 0.5 % albedo
0.932 μm	0.90 - 0.965 μm	3.0. @ 0.5 % albedo
1.600 μm	1.55 - 1.64 μm	3.0. @ 0.5 % albedo
3.740 μm	3.55 - 3.93 μm	0.40 K @ 300 K
10.80 μm	10.3 - 11.3 μm	0.22 K @ 300 K
12.00 μm	11.5 - 12.5 μm	0.22 K @ 300 K

MWHS	Micro-Wave Humidity Sounder
Satellites	**FY-3 A to G**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2021
Mission	Humidity sounding in nearly-all-weather conditions
Instrument type	5-channel MW radiometer
Scanning technique	Cross-track: .... steps of ...... km ssp, swath 2250 km - Along-track: one .....-km line each ..... s
Coverage/cycle	Global coverage once/day
Resolution (s.s.p.)	15 km IFOV

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy
150	2000	V, H	0.9 K
183.31 ± 7.0	2000	....	0.9 K
183.31 ± 3.0	1000	....	0.9 K
183.31 ± 1.0	500	....	1.1 K

MWRI	**Micro-Wave Radiation Imager**
Satellites	**FY-3 A to G**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2021
Mission	Multi-purpose MW imager
Instrument type	6-frequency, 12-channel MW radiometer
Scanning technique	Conical: 53.1° zenith angle, swath 1400 km – Scan rate: .... scan/min = ... km/scan
Coverage/cycle	Global coverage once/day
Resolution (constant)	Changing with frequency, consistent with an antenna diameter of ..... x .... cm

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy	IFOV	Pixel
....	....	V, H	.... K	..... x ..... km	...... x ...... km
....	....	V, H	.... K	..... x ..... km	...... x ...... km
....	....	V, H	.... K	..... x ..... km	...... x ...... km
....	....	V, H	.... K	..... x ..... km	...... x ...... km
....	....	V, H	.... K	..... x ..... km	...... x ...... km
....	....	V, H	.... K	..... x ..... km	...... x ...... km

MWTS	**Micro-Wave Temperature Sounder**
Satellites	**FY-3 A to G**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2021
Mission	Temperature sounding in nearly-all-weather conditions
Instrument type	4-channel MW radiometer
Scanning technique	Cross-track: .... steps of ...... km ssp, swath 2250 km - Along-track: one .....-km line each ..... s
Coverage/cycle	Global coverage once/day
Resolution (s.s.p.)	70 km IFOV

Central frequency (GHz)	Bandwidth (MHz)	Polarisation	Accuracy
50.30	180	....	0.50 K
53.596 ± 0.115	340	....	0.40 K
54.94	400	....	0.40 K
57.290	330	....	0.40 K

OMPS	**Ozone Mapping and Profiler Suite**
Satellites	**NPP, NPOESS 2 and 5**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2025
Mission	Ozone total column and profile, total columns or gross profiles of other species
Instrument type	Three UV/VIS/NIR grating spectrometers for mapping, nadir profiling and limb sounding respectively
Scanning technique	Mapper: cross-track swath 2800 km, along-track one 50-km line in 7.6 s. Nadir profiler: one along-track sounding each 38 s (250 km). Limb sounder: 1-km vertical steps between 10 and 60 km
Coverage/cycle	Global coverage: mapper once/day, nadir profiler in 6 days, limb sounder in 4 days. Daylight only
Resolution (s.s.p.)	Mapper: 50 km. Nadir profiler: 250 km. Limb sounder: about 300 km

Subsystem	Spectral range	Spectral resolution	SNR at specified input radiance
Cross-track mapper for total ozone	300 - 380 nm	1 nm	1000
Nadir-viewing ozone profiler	250 - 310 nm	1 nm	35 (at 250 nm) to 400 (at 310 nm)
Limb scanning	290 - 1000 nm	1.5 to 40 nm	320 (at 290 nm) to 1200 (at 600 nm)

Radiomet	**Radio-occultation sounder**
Satellites	**Meteor-3M N2 and N3**
Status (end 2003)	**Being built** – Utilisation period: 2005 to ~ 2012
Mission	Temperature/humidity sounding with highest vertical resolution, space weather
Instrument type	GPS receiver measuring the phase delay due to refraction during occultation between GPS and LEO
Scanning technique	Limb scanning from 830 km to close-to-surface by time sampling – Azimuth 90° fore- and aft-
Coverage/cycle	About 500 soundings/day – Average spacing 1000 km – Global coverage (300 km spacing) in 10 days
Resolution	About 300 km

SAGE-III	**Stratospheric Aerosol and Gas Experiment – III**
Satellites	**Meteor-3M N1**
Status (end 2003)	**Operational** – Utilisation period: 2001 to ~ 2005
Mission	Vertical profile of aerosol, ozone and other species in the upper troposphere and stratosphere
Instrument type	UV/VIS/NIR/SWIR (290-1550 nm) 9-band solar and lunar occultation grating spectrometer
Scanning technique	Sun and moon tracking during the occultation phase, 1-km step from ~ 10 to ~ 85 km
Coverage/cycle	N/A (few tens of events/day)
Resolution (vertical)	1-2 km

SBUV/2	**Solar Backscatter Ultraviolet / 2**
Satellites	**NOAA 9 to 19 except 12 and 15**
Status (end 2003)	**Operational** – Utilisation period: 1984 to ~ 2012
Mission	Vertical profile of ozone and other species. Solar irradiance
Instrument type	UV spectro-radiometer. Either 12 discrete 1-nm bandwidth channels selectable in the interval 252 to 340 nm, or continuous sweep from 160 to 340 nm.
Scanning technique	Nadir view only
Coverage/cycle	About 1650 measurements/day. Global coverage (170 km spacing) in 10 days, in daylight
Resolution	170 km

SEVIRI	**Spinning Enhanced Visible Infra-Red Imager**
Satellites	**Meteosat 8 to 11 (Meteosat Second Generation)**
Status (end 2003)	**Commissioned** – Utilisation period: 2002 to ~ 2018
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	12-channel VIS/IR radiometer (11 narrow-bandwidth, 1 high-resolution broad-bandwidth VIS)
Coverage/cycle	Full disk each 15 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	4.8 km IFOV, 3 km sampling for narrow channels; 1.4 km IFOV, 1 km sampling for broad VIS channel

Central wavelength	**Spectral interval** (99 % encircled energy)	**Radiometric accuracy**
N/A (broad bandwidth channel)	0.6 - 0.9 μm	10 @ 1 % albedo
0.635 μm	0.56 - 0.71 μm	30 @ 1 % albedo
0.81 μm	0.74 - 0.88 μm	20 @ 1 % albedo
1.64 μm	1.50 - 1.78 μm	10 @ 1 % albedo
3.92 μm	3.48 - 4.36 μm	0.17 K @ 300 K
6.25 μm	5.35 - 7.15 μm	0.21 K @ 250 K
7.35 μm	6.85 - 7.85 μm	0.12 K @ 250 K
8.70 μm	8.30 - 9.10 μm	0.10 K @ 300 K
9.66 μm	9.38 - 9.94 μm	0.29 K @ 255 K
10.8 μm	9.80 - 11.8 μm	0.11 K @ 300 K
12.0 μm	11.0 - 13.0 μm	0.15 K @ 300 K
13.4 μm	12.4 - 14.4 μm	0.37 K @ 270 K

SFM-2	Ultraviolet spectrometer
Satellites	**Meteor-3M N1**
Status (end 2003)	**Operational** – Utilisation period: 2001 to ~ 2005
Mission	Vertical profile of ozone
Instrument type	UV spectrometer
Scanning technique	
Coverage/cycle	
Resolution	

SOUNDER	GOES Sounder
Satellites	**GOES 8 to 15**
Status (end 2003)	**Operational** – Utilisation period: 1994 to ~ 2015
Mission	Temperature/humidity sounding
Instrument type	19-channel IR radiometer (including one VIS)
Coverage/cycle	Full disk in 8 h, 3000x3000 km^2 in 42 min, 1000x1000 km^2 in 5 min
Resolution (s.s.p.)	8.0 km

Wavelength	Wavenumber	Bandwidth	Radiometric accuracy
14.71 μm	680 cm^{-1}	13 cm^{-1}	1.24 K @ 290 K
14.37 μm	696 cm^{-1}	13 cm^{-1}	0.79 K @ 290 K
14.06 μm	711 cm^{-1}	13 cm^{-1}	0.68 K @ 290 K
13.64 μm	733 cm^{-1}	16 cm^{-1}	0.55 K @ 290 K
13.37 μm	748 cm^{-1}	16 cm^{-1}	0.49 K @ 290 K
12.66 μm	790 cm^{-1}	30 cm^{-1}	0.23 K @ 290 K
12.02 μm	832 cm^{-1}	50 cm^{-1}	0.14 K @ 290 K
11.03 μm	907 cm^{-1}	50 cm^{-1}	0.10 K @ 290 K
9.71 μm	1030 cm^{-1}	25 cm^{-1}	0.12 K @ 290 K
7.43 μm	1345 cm^{-1}	55 cm^{-1}	0.06 K @ 290 K
7.02 μm	1425 cm^{-1}	80 cm^{-1}	0.06 K @ 290 K
6.51 μm	1535 cm^{-1}	60 cm^{-1}	0.15 K @ 290 K
4.57 μm	2188 cm^{-1}	23 cm^{-1}	0.20 K @ 290 K
4.52 μm	2210 cm^{-1}	23 cm^{-1}	0.17 K @ 290 K
4.45 μm	2248 cm^{-1}	23 cm^{-1}	0.20 K @ 290 K
4.13 μm	2420 cm^{-1}	40 cm^{-1}	0.14 K @ 290 K
3.98 μm	2513 cm^{-1}	40 cm^{-1}	0.22 K @ 290 K
3.74 μm	2671 cm^{-1}	100 cm^{-1}	0.14 K @ 290 K
0.70 μm	N/A	0.05 μm	.... @ .... % albedo

SOUNDER	INSAT Sounder
Satellites	**INSAT-3D**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2010
Mission	Temperature/humidity sounding
Instrument type	19-channel IR radiometer (including one VIS)
Coverage/cycle	Full disk in .... h. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	10.0 km

Wavelength	Wavenumber	Bandwidth	Radiometric accuracy
14.71 μm	680 cm^{-1}	13 cm^{-1}	1.5 K @ 300 K
14.37 μm	696 cm^{-1}	13 cm^{-1}	1.00 K @ 300 K
14.06 μm	711 cm^{-1}	13 cm^{-1}	0.50 K @ 300 K
13.96 μm	716 cm^{-1}	16 cm^{-1}	0.50 K @ 300 K
13.37 μm	748 cm^{-1}	16 cm^{-1}	0.50 K @ 300 K
12.66 μm	790 cm^{-1}	30 cm^{-1}	0.30 K @ 300 K
12.02 μm	832 cm^{-1}	50 cm^{-1}	0.15 K @ 300 K
11.03 μm	907 cm^{-1}	50 cm^{-1}	0.15 K @ 300 K
9.71 μm	1030 cm^{-1}	25 cm^{-1}	0.20 K @ 300 K
7.43 μm	1345 cm^{-1}	55 cm^{-1}	0.20 K @ 300 K
7.02 μm	1425 cm^{-1}	80 cm^{-1}	0.20 K @ 300 K
6.51 μm	1535 cm^{-1}	60 cm^{-1}	0.20 K @ 300 K
4.57 μm	2188 cm^{-1}	23 cm^{-1}	0.15 K @ 300 K
4.52 μm	2210 cm^{-1}	23 cm^{-1}	0.15 K @ 300 K
4.45 μm	2248 cm^{-1}	23 cm^{-1}	0.15 K @ 300 K
4.13 μm	2420 cm^{-1}	40 cm^{-1}	0.15 K @ 300 K
3.98 μm	2513 cm^{-1}	40 cm^{-1}	0.15 K @ 300 K
3.74 μm	2671 cm^{-1}	100 cm^{-1}	0.15 K @ 300 K
0.70 μm	N/A	0.05 μm	.... @ .... % albedo

SSM/I	**Special Sensor Microwave - IMAGER**
Satellites	**DMSP F 8, 10, 11, 13, 14 and 15**
Status (end 2003)	**Operational** – Utilisation period: 1987 to ~ 2005
Mission	Multi-purpose MW imager
Instrument type	4-frequency, 7-channel MW radiometer
Scanning technique	Conical: 53.1° zenith angle, swath 1400 km – Scan rate: 31.9 scan/min = 12.5 km/scan
Coverage/cycle	Global coverage once/day
Resolution (constant)	Changing with frequency, consistent with an antenna diameter of 61 x 66 cm

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy	IFOV	Pixel
19.35	400	V, H	0.43 K	45 x 68 km	25.0 x 12.5 km
22.235	400	V	0.73 K	40 x 60 km	25.0 x 12.5 km
37.0	1500	V, H	0.38 K	24 x 36 km	25.0 x 12.5 km
85.5	3000	V, H	0.71 K	11 x 16 km	12.5 x 12.5 km

SSM/T	**Special Sensor Microwave - Temperature**
Satellites	**DMSP F 4 to 15**
Status (end 2003)	**Operational** – Utilisation period: 1979 to ~ 2005
Mission	Temperature sounding in nearly-all-weather conditions
Instrument type	7-channel MW radiometer
Scanning technique	Cross-track: 7 steps of 174 km ssp, swath 1500 km - Along-track: one 48-km line each 8 s
Coverage/cycle	Global coverage once/day
Resolution (s.s.p.)	200 km IFOV

Central frequency (GHz)	Bandwidth (MHz)	Polarisation	Accuracy
50.50	400	H	0.60 K
53.20	400	H	0.40 K
54.35	400	H	0.40 K
54.90	400	H	0.40 K
58.40	350	H	0.50 K
58.825	300	H	0.40 K
59.40	250	H	0.40 K

SSM/T-2	**Special Sensor Microwave - Humidity**
Satellites	**DMSP F 11, 12, 14, 15**
Status (end 2003)	**Operational** – Utilisation period: 1991 to ~ 2005
Mission	Humidity sounding in nearly-all-weather conditions
Instrument type	5-channel MW radiometer
Scanning technique	Cross-track: 28 steps of 42 km ssp, swath 1500 km - Along-track: one 48-km line each 8 s
Coverage/cycle	Global coverage once/day
Resolution (s.s.p.)	48 km IFOV

Central frequency (GHz)	Bandwidth (MHz)	Polarisation	Accuracy
91.655 ± 1.250	3000	H	0.6 K
150.0 ± 1.250	1500	H	0.6 K
183.31 ± 7.0	500	H	0.6 K
183.31 ± 3.0	1000	H	0.6 K
183.31 ± 1.0	1500	H	0.8 K

SSMIS	**Special Sensor Microwave – Imager/Sounder**
Satellites	**DMSP F 16 and DMSP S 17 to 20**
Status (end 2003)	**Close to be launched** – Utilisation period: 2003 to ~ 2015
Mission	Multi-purpose MW imager with temperature/humidity sounding channels for improved precipitation
Instrument type	21-frequency, 24-channel MW radiometer
Scanning technique	Conical: 53.1° zenith angle, swath 1700 km – Scan rate: 31.9 scan/min = 12.5 km/scan
Coverage/cycle	Global coverage once/day
Resolution (constant)	Changing with frequency, consistent with an antenna diameter of 61 x 66 cm

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy	IFOV	Pixel
19.35	400	V, H	0.7 K	45 x 68 km	25.0 x 12.5 km
22.235	400	V	0.7 K	40 x 60 km	25.0 x 12.5 km
37.0	1500	V, H	0.5 K	24 x 36 km	25.0 x 12.5 km
50.3	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
52.8	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
53.596	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
54.4	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
55.5	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
57.29	350	-	0.5 K	18 x 27 km	37.5 x 12.5 km
59.4	250	-	0.6 K	18 x 27 km	37.5 x 12.5 km
60.792668 ± 0.357892 ± 0.050	120	V + H	0.7 K	18 x 27 km	37.5 x 12.5 km
60.792668 ± 0.357892 ± 0.016	32	V + H	0.6 K	18 x 27 km	75.0 x 12.5 km
60.792668 ± 0.357892 ± 0.006	12	V + H	1.0 K	18 x 27 km	75.0 x 12.5 km
60.792668 ± 0.357892 ± 0.002	6	V + H	1.8 K	18 x 27 km	75.0 x 12.5 km
60.792668 ± 0.357892	3	V + H	2.4 K	18 x 27 km	75.0 x 12.5 km
63.283248 ± 0.285271	3	V + H	2.4 K	18 x 27 km	75.0 x 12.5 km
91.655	3000	V, H	0.9 K	10 x 15 km	12.5 x 12.5 km
150	1500	H	0.9 K	.... x .... km	37.5 x 12.5 km
183.31 ± 6.6	1500	H	1.2 K	.... x .... km	37.5 x 12.5 km
183.31 ± 3.0	1000	H	1.0 K	.... x .... km	37.5 x 12.5 km
183.31 ± 1.0	500	H	1.2 K	.... x .... km	37.5 x 12.5 km

S-VISSR	**Stretched Visible and Infrared Spin Scan Radiometer**
Satellites	**FY-2 A to E**
Status (end 2003)	**Operational** – Utilisation period: 1997 to ~ 2014
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	5-channel VIS/IR radiometer
Coverage/cycle	Full disk each 30 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	5.0 km for IR channels; 1.25 km for the VIS channel

Central wavelength	Spectral interval	Radiometric accuracy
0.77 µm	0.55 - 0.99 µm	1.5 @ 0.5 % albedo
3.75 µm	3.50 - 4.00 µm	0.4 K @ 300 K
6.95 µm	6.30 - 7.60 µm	0.5 K @ ..... K
10.8 µm	10.3 - 11.3 µm	0.3 K @ 300 K
12.0 µm	11.5 - 12.5 µm	0.3 K @ 300 K

TOU/SBUS	**Total Ozone Unit and Solar Backscatter Ultraviolet Sounder**
Satellites	**FY-3 A to G**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2021
Mission	Ozone total column and vertical profile
Instrument type	Two UV spectro-radiometers. TOU with 6 channels of 1.2 nm bandwidth in the range 308-360 nm, SBUS with 12 discrete channels of 1 nm bandwidth in the range 252-380 nm
Scanning technique	TOU cross-track scanning, swath 3000 km, SBUS nadir view only
Coverage/cycle	TOU: global coverage once/day. SBUS: global coverage (200 km spacing) in 10 days. Daylight
Resolution	50 km for total ozone from TOU, 200 km for ozone profile from SBUS

VHRR (in GEO)	**Very High Resolution Radiometer**
Satellites	**INSAT-1 A/B/C/D, INSAT-2 A/B/D/E, INSAT-3A, Kalpana-1 (former MetSat), Kalpana-2**
Status (end 2003)	**Operational** – Utilisation period: 1982 to ~ 2010
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	3-channel VIS/IR radiometer
Coverage/cycle	Full disk each 3 hours, more frequently on demand. Half-hourly triplets around 00 and 12 UT for winds
Resolution (s.s.p.)	8.0 km for IR channels; 2 km for the VIS channel

Central wavelength	Spectral interval	Radiometric accuracy
0.65 µm	0.55 - 0.75 µm	.... @ ..... % albedo
6.40 µm	5.70 - 7.10 µm	.... K @ ..... K
11.5 µm	10.5 - 12.5 µm	.... K @ 300 K

VIIRS	**Visible/Infrared Imager Radiometer Suite**
Satellites	**NPP, NPOESS 1 to 6**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2026
Mission	Multi-purpose VIS/IR imagery, including ocean colour
Instrument type	22-channel VIS/IR radiometer, including a day/night 0.7 µm channel
Scanning technique	Cross-track: 16 parallel lines sampled by 2048 pixel of 800 m ssp and 32 parallel lines sampled by 4096 pixel of 400 m ssp; swath 3000 km. Along-track: one 11.9-km strip of 16 or 32 lines in 1.786 s.
Coverage/cycle	Global coverage twice/day (IR) or once/day (VIS)
Resolution (s.s.p.)	400 m for five AVHRR-like channels and the VIS day/night channel, 800 m for all other channels

Channel set and resolution	Central wavelength	Bandwidth or Spectral interval	Radiometric accuracy
High-quality radiometric channels, resolution 800 m	412 nm	20 nm	.... @ .... % albedo
	445 nm	18 nm	.... @ .... % albedo
	488 nm	20 nm	.... @ .... % albedo
	555 nm	20 nm	.... @ .... % albedo
	672 nm	20 nm	.... @ .... % albedo
	746 nm	15 nm	.... @ .... % albedo
	865 nm	39 nm	.... @ .... % albedo
	1240 nm	20 nm	.... @ .... % albedo
	1378 nm	15 nm	.... @ .... % albedo
	1610 nm	60 nm	.... @ .... % albedo
	2250 nm	50 nm	.... @ .... % albedo
	3.70 μm	0.18 μm	...... K @ 300 K
	4.05 μm	0.155 μm	...... K @ 300 K
	8.55 μm	0.30 μm	...... K @ 300 K
	10.763 μm	1.00 μm	...... K @ 300 K
	12.013 μm	0.95 μm	...... K @ 300 K
Day/night band, resolution 400 m	0.7 μm	0.5 - 0.9 μm	.... @ .... % albedo
High-resolution imaging channels, resolution 400 m	0.64 μm	0.60 - 0.68 μm	.... @ .... % albedo
	0.865 μm	0.845 - 0.884 μm	.... @ .... % albedo
	1.61 μm	1.58 - 1.64 μm	.... @ .... % albedo
	3.74 μm	3.55 - 3.93 μm	...... K @ 300 K
	11.45 μm	10.5 - 12.4 μm	...... K @ 300 K

VIRI-M	**Visible Infra Red Imager for MetOp**
Satellites	**MetOp-3**
Status (end 2003)	**Being defined** – To be utilised in the period: 2015 to ~ 2019
Mission	Multi-purpose VIS/IR imagery
Instrument type	11-channel VIS/IR radiometer
Scanning technique	Cross-track: 2048 pixel of 800 m ssp, swath 2900 km - Along-track: six 1.1-km lines/s
Coverage/cycle	Global coverage twice/day (IR) or once/day (VIS)
Resolution (s.s.p.)	1.1 km

Central wavelength	Bandwidth	Radiometric accuracy
0.443 μm	0.02 μm	20 @ 0.5 % albedo
0.670 μm	0.02 μm	20 @ 0.5 % albedo
0.865 μm	0.02 μm	20 @ 0.5 % albedo
1.375 μm	0.03 μm	40 @ 0.5 % albedo
1.610 μm	0.03 μm	40 @ 0.5 % albedo
3.74 μm	0.38 μm	0.1 K @ 300 K
6.70 μm	0.36 μm	0.3 K @ 250 K
8.70 μm	0.30 μm	0.1 K @ 300 K
10.8 μm	1.0 μm	0.1 K @ 300 K
12.0 μm	1.0 μm	0.1 K @ 300 K
13.4 μm	0.3 μm	0.2 K @ 270 K

VIRR	Visible and Infra Red Radiometer
Satellites	**FY-3 A to G**
Status (end 2003)	**Being built** – Utilisation period: 2006 to ~ 2021
Mission	Multi-purpose VIS/IR imagery with emphasis on vegetation and ocean colour
Instrument type	10-channel VIS/IR radiometer
Scanning technique	Cross-track: 2048 pixel of 800 m ssp, swath 2800 km - Along-track: six 1.1-km lines/s
Coverage/cycle	Global coverage twice/day (IR) or once/day (VIS)
Resolution (s.s.p.)	1.1 km IFOV

Central wavelength	Spectral interval	Radiometric accuracy
0.455 µm	0.43 - 0.48 µm	.... @ .... % albedo
0.505 µm	0.48 - 0.53 µm	.... @ .... % albedo
0.555 µm	0.53 - 0.58 µm	.... @ .... % albedo
0.630 µm	0.58 - 0.68 µm	.... @ .... % albedo
0.865 µm	0.84 – 0.89 µm	.... @ .... % albedo
1.360 µm	1.325 - 1.395 µm	.... @ .... % albedo
1.600 µm	1.55 - 1.64 µm	.... @ .... % albedo
3.740 µm	3.55 - 3.93 µm	.... K @ 300 K
10.80 µm	10.3 - 11.3 µm	.... K @ 300 K
12.00 µm	11.5 - 12.5 µm	.... K @ 300 K