Meteorological Satellite Status Report

For

SPAWAR Systems Center Charleston

Aviation Technical Services and Engineering Division (Code 36)
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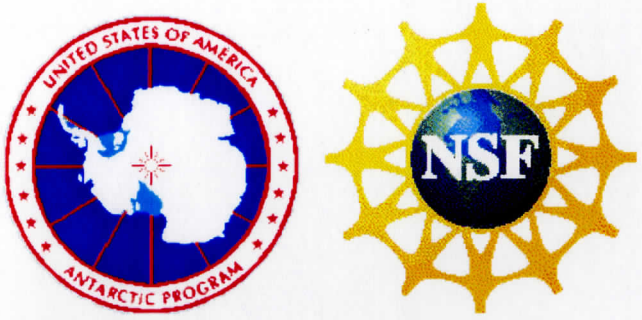


Abstract

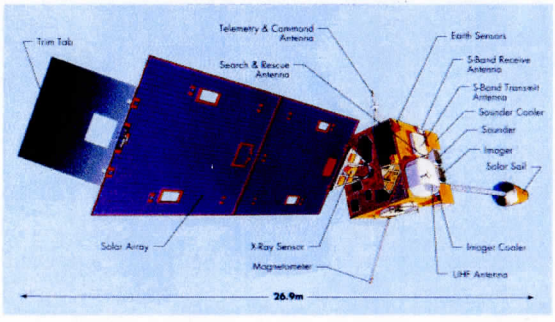
Meteorological satellites are one of the most critical observing tools available to operational Antarctic weather forecasters and decision-makers. Having this information affords improved weather forecasts and ultimately increased safety for those working and traveling in and around the Antarctic. This report reviews the status of both operational and research meteorological satellites, including those impacting the Antarctic. The current uses, limitations, and potential applications of meteorological satellites acquired by the United States Antarctic Program (USAP) are outlined. Future meteorological satellite launches are also discussed. Meteorological satellites that are currently not acquired or available to the USAP are reviewed, including their applications, benefits, limiting factors and other miscellaneous considerations.

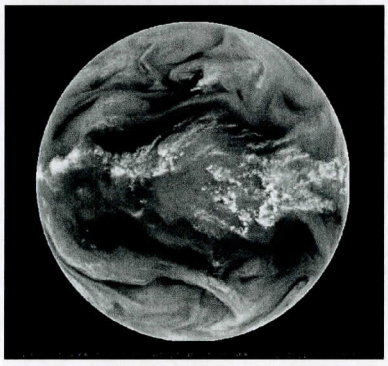
Operational and research satellites

At this time, a series of operational and research polar orbiting and geostationary satellites are available for use. This is a review of their current status.

Geostationary Operational

Geostationary Operational Environmental Satellite (GOES)

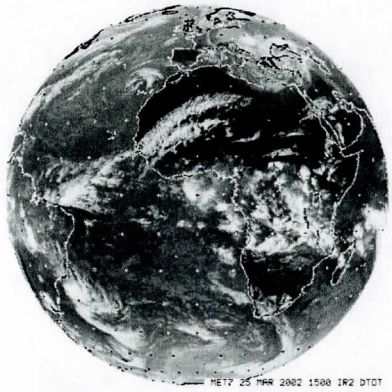




The Geostationary Operational Environmental Satellite (GOES) operated by the National Oceanic and Atmospheric Administration (NOAA), United States, currently has five satellites in orbit. GOES-8 and GOES-10 are the current operational satellites, with GOES-9, GOES-11, and GOES-12 currently in on-orbit storage. Currently, GOES-8 is the oldest satellite and has some problems, most of which are transparent to users. This satellite is nearly beyond its life expectancy. GOES-9, which is on-orbit storage, has limited use due to some attitude control problems. Recently NOAA has agreed to activate GOES-9 to lend it to the Japanese Meteorological Agency (JMA) to assist with coverage over the Far East (see GMS). GOES-11, also in on-orbit storage, is a fully functional satellite ready for use as a backup within 48 hours. GOES-12, the newest satellite recently launched, tested, and placed into on-orbit storage in December of 2001, is likely to be the first satellite taken out of storage to replace either GOES-8 or GOES-10. GOES-12 has the first X-ray imager for space weather applications, which makes

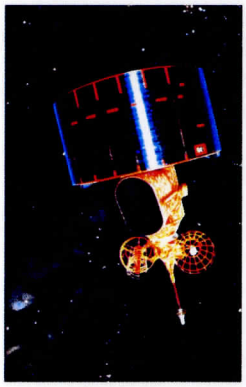
this satellite desirable to have in operation. All GOES satellites in this generation are 3-axis stabilized satellites offering visible, short & long wave and window infrared, as well as water vapor data. The GOES satellites also offer a 19 channel sounder; however, they do not cover below 60 degrees South or the Antarctic at all.

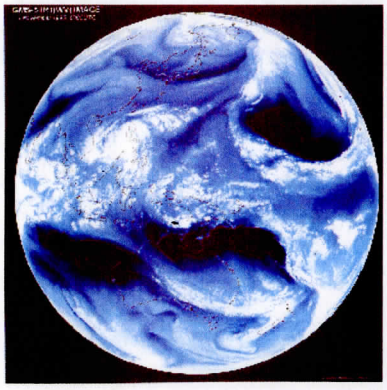
Meteosat



The Meteosat Operational Program (MOP) is overseen by EUMETSAT (Europe). After the end of the intensive field campaign for INDOEX in 1998 and early 1999, the EUMETSAT Council agreed to leave Meteosat-5 at a position around 63°E to further extend the Indian Ocean Data Coverage (IODC) until the end of the year 2003. This satellite is nearly beyond its life span and is starting to acquire almost a 1-degree inclination. Meteosat-6 is the in-orbit stand-by spacecraft and is located around 9°W. It is noteworthy that the rapid scanning service minor gain has an anomaly on the imager. Meteosat-7 is the operational spacecraft at a position of 0° (since 3 June 1998). All MOP satellites are spinner satellites offering visible, infrared and water vapor data.

Geostationary Meteorological Satellite (GMS or Himawari)

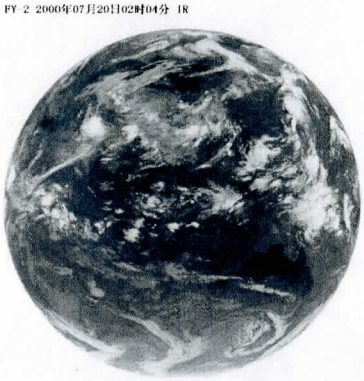




The Japanese Geostationary Meteorological Satellite (GMS) or Himawari satellite, currently GMS-5, is the only geostationary satellite in operational mode overseen by the Japanese Meteorological Agency (JMA). Currently the satellite has over a 1-degree inclination, which is increasing to as much as 3 degrees by 2004. Due to the need to keep this satellite in operation as

long as possible, imaging over the Southern Ocean and Antarctic has been suspended. Due to the possibility of GMS-5 failing before a replacement can be launched, NOAA has agreed to lend the JMA GOES-9. As of this writing there is no timetable set as to when this will take place. The GMS satellite series is a spinning satellite series, offering visible, short wave and window infrared and water vapor data.

Feng Yun 2 (FY-2)



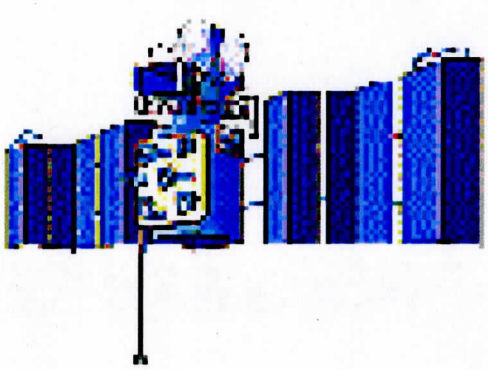
The Chinese geostationary satellite series, operated by the Chinese Meteorological Agency (CMA) is Feng Yun 2 (FY-2, Feng Yun means Wind and Cloud). The first satellite, FY-2A, is of limited use due to de-spin subsystem problems and S-Band antenna problems and has been operated as only an experimental satellite. The operational satellite, FY-2B, is turned off for eclipse seasons (the most recent was 25 February 2002 to 10 April 2002). In 2001, CMA had problems getting FY-2 to come out of eclipse shutdown. FY-2 is located at 105 degrees East and, like its experimental sister, it is a three channel (visible, infrared, and water vapor) spinner satellite.

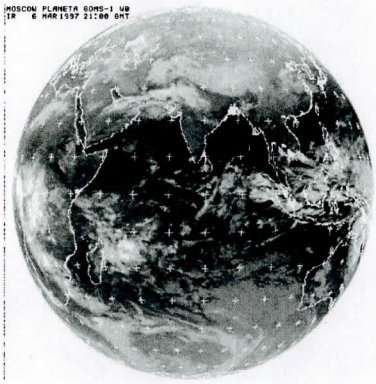
INSAT

The India Meteorological Department (IMD) operates the INSAT series of geostationary satellites. These satellites are shared for meteorological and communications use. Currently, the operational and back up satellites include INSAT I-D, II-A, II-B, II-E, III-B, and III-C, located at

74, 83 and 93.5 degrees East. The INSAT constellation includes both spinner (older series) and 3-axis stabilized satellites, most with the 5 channel Very High Resolution Radiometer (VHRR) sensors including visible, infrared and water vapor channels. Some INSAT satellites also have Charge Coupled Device (CCD) cameras. All of the meteorological data from the INSAT satellites is encrypted. However, NOAA and IMD have made arrangements to share data. Unfortunately, the US has not worked the navigation and calibration of the INSAT data at this time.

Geostationary Operational Meteorological Satellite (GOMS/Elektro)

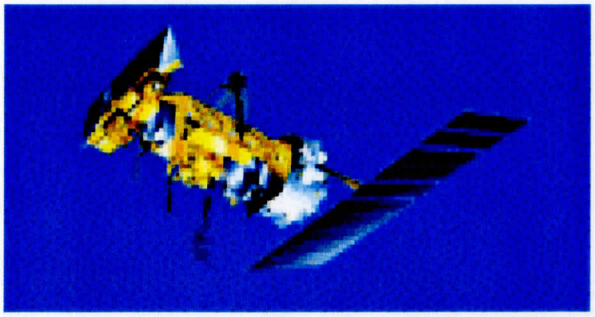


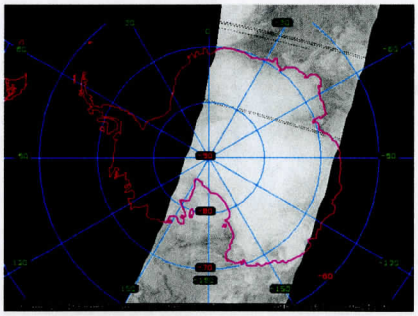


The Russian Planeta-C Meteorological Space System includes Elektro or the Geostationary Operational Meteorological Satellite (GOMS). GOMS-N1 has been in orbit and in stand-by mode since September 1998. It has provided very little imagery since it was launched and placed on orbit. This 3-axis stabilized satellite offers two channels - visible and infrared.

Polar Orbiting Operational

Polar Operational Environmental Satellite (POES)

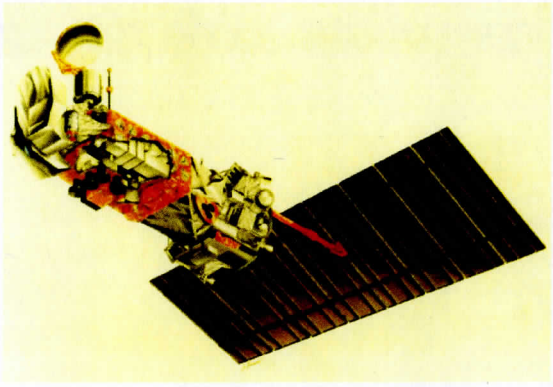


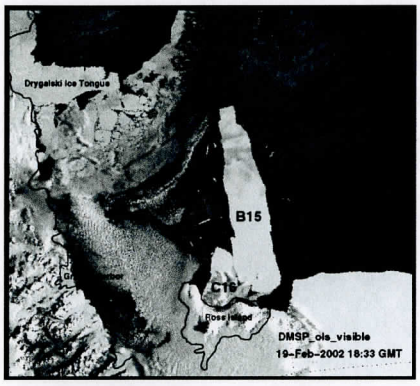


The Polar Operational Environmental Satellite (POES) system operated by NOAA, United States, currently has five satellites in orbit. Currently, NOAA-16 and NOAA-14 are operational, with NOAA-15, NOAA-12 and NOAA-11 in backup or limited use mode. NOAA-16, the most recently launched POES, has an afternoon (2 p.m. local) equatorial cross time. This satellite is

fully functional, with the exception of the Automatic Picture Transmission (APT) system, which has been beset with problems. This satellite is the second of the NOAA-KLM series of satellites, which host a new/updated suite of satellite instruments and sensors. NOAA-15, which is the other NOAA-KLM series satellite, has a morning (7:30 a.m. local) equatorial cross time. This satellite is also functional, but has had problems with its imager (the Advanced Very High Resolution Radiometer (AVHRR)) and sounder (the High resolution Infrared Radiation Sounder (HIRS)) instruments. It has also is transmitting from its backup antenna system after a failure with its primary system. NOAA-14, which has an older suite of satellite instrumentation, is an afternoon (2 p.m. local) equatorial cross-time satellite. It is functional, but its AVHRR unit has had problems, making the data unusable. NOAA-12 is a morning (6:40 a.m. local) cross-time satellite that is currently functioning well, with the exception of sounding instruments. Finally, the NOAA-11 satellite is operating in an afternoon (2 p.m. local) cross time. NOAA-11 is used for limited sounding data only, as its imager has failed. All NOAA satellites also offer a microwave sounder instrument(s) as well.

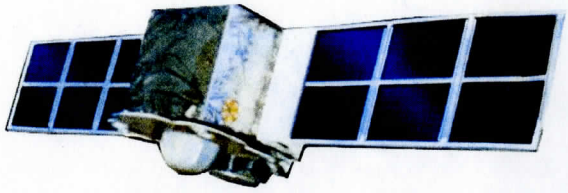
Defense Meteorological Satellite Program (DMSP)

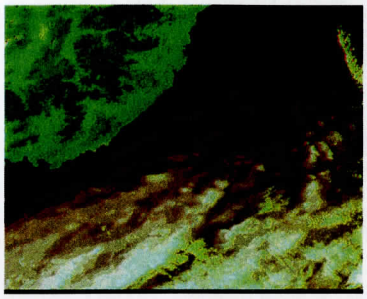




The Defense Meteorological Satellite Program (DMSP) satellite system is a polar orbiting satellite series, operated by the United States (NOAA) for both military and civilian (in non-real-time) use. Over the Antarctic (south of 60 degrees South), the DMSP send clear transmissions in what would otherwise be an encrypted satellite data signal. Current operational satellites are the DMSP F-13 (17:40 early morning) and DMSP F-15 (21:45 morning). The backup satellites are DMSP F-11 (19:32 early morning), DMSP F-12 (21:13 morning), and DMSP F-14 (20:43 morning). These satellites offer a high resolution imager of infrared and visible data and microwave sounder data.

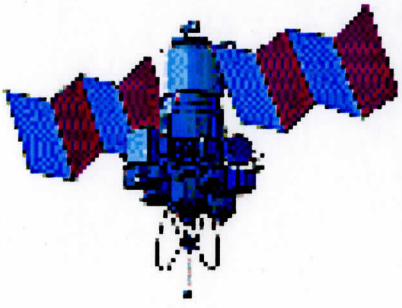
Feng Yun (FY-1)

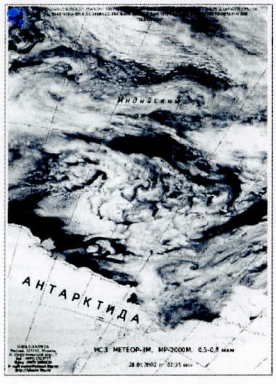




The Feng Yun (FY-1) is the operational polar orbiting satellite series operated by the Chinese Meteorological Agency for China. Currently, FY-1C is the operational satellite, despite some recent problems that required the switch from the A-side to B-side electronics. On May 15, 2002 the next FY-1 satellite, FY-1D, was launched. Initial reports from the Chinese and the amateur satellite community state that FY-1D was taking good imagery within hours after its launch. The same launch vehicle also placed China's first oceanographic polar orbiting satellite, Hai Yang (HY-1), into orbit as well. It is important to note that the FY-1 series of satellites are not encrypted and transmit in the free and clear for users worldwide to use, including the Antarctic.

Meteor

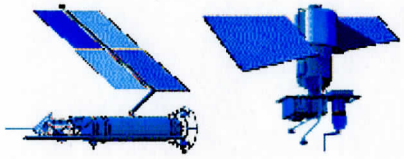


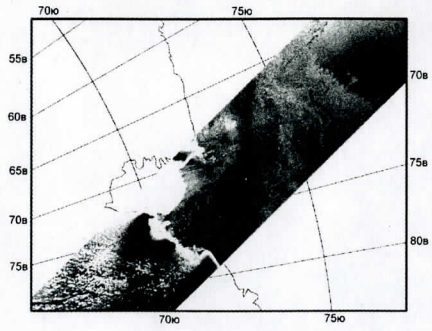


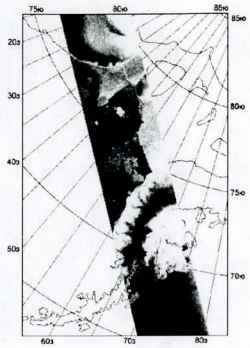
28/01/2002 07:35 (0.5-0.8um)

The Russian Federation operates the Meteor polar orbiting satellite system. Two of the satellites in that system, Meteor 2-21 and 3-5, are both non-sun-synchronous satellites. They have the opportunity to offer imagery where most other polar orbiting satellites are not orbiting, in a geographic sense. However, these satellite are often turned off and on with little or no notice, are well beyond their design life, and only offer Automatic Picture Transmission (APT) visible and infrared imagery. The third satellite in the series, Meteor 3M, was launched in 2001 and is currently in a pre-operations period. This satellite is a sun-synchronous satellite. It appears that Meteor 2-21 and 3-5 are the last operating non-sun-synchronous polar orbiting satellites.

Resurs and Okean



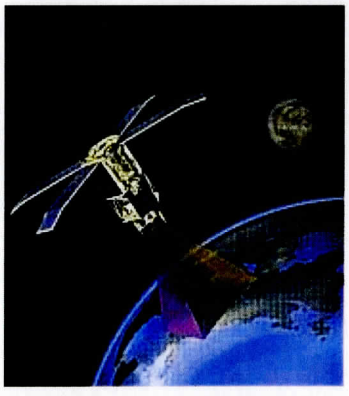


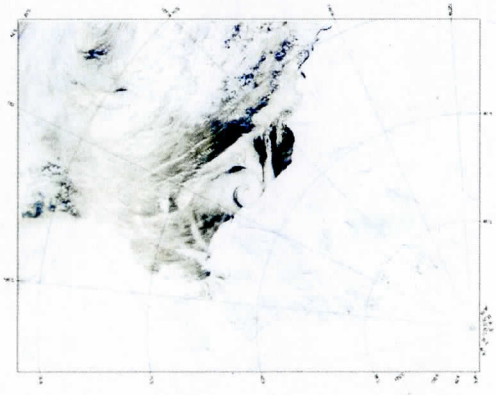


The Russian Federation and the Ukraine jointly operate two series of satellites, Resurs and Okean. Resurs-01 N3, Resurs-01 N4 and Okean-1 N7 are the currently operating satellites. Resurs is an earth resources satellite, with some similarities to the US Landsat satellite. Okean is an oceanographic satellite. Typically Resurs satellite data is only available within sight of Russian and Ukrainian ground stations. The Resurs hosts a multi-channel scanning unit and a side looking radar.

Research

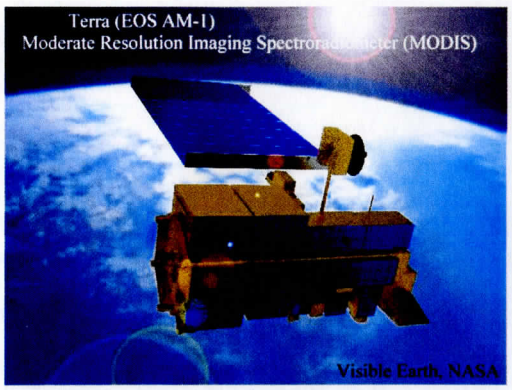
Orbview-2/SeaStar

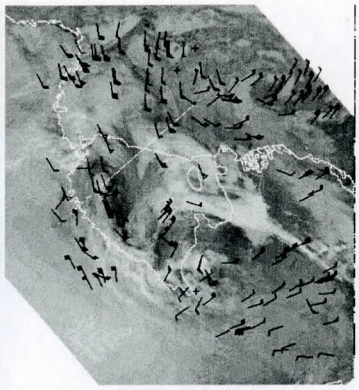




Orbital Science Corporation in conjunction with NASA operates the Orbview-2/SeaStar polar orbiting satellite, which has the SeaWiFS instrument (a Coastal Zone Color Scanner). These data are made available in real-time to the weather forecasters at McMurdo Station, Antarctica and are used for science projects in the Antarctic by the USAP. However, these data are encrypted, thus requiring a decryption unit. They are also available for science use, with permission from NASA. The data from SeaWiFS offers a variety of visible channel data for ocean color applications as well as infrared data.

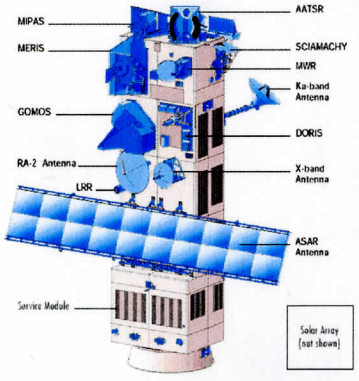
Earth Observing System (EOS)

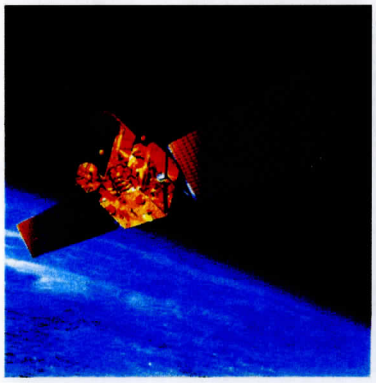


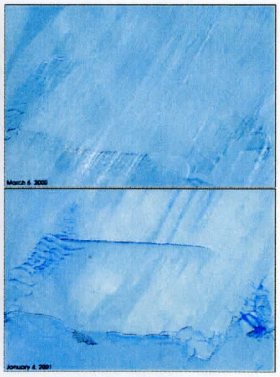


NASA's Mission to Planet Earth (MTPE) includes an Earth Observing System (EOS). This system offers a series of research polar orbiting satellites with the aim of studying the Earth system. The flag satellites of EOS are Terra, launched in 1999, and Aqua, just launched on 4 April 2002. These satellites offer a suite of instruments and sensor systems. The two that are of most note and most critical to Antarctic weather forecasting are the Moderate Resolution Imaging Spectroradiometer (MODIS) and Atmospheric Infrared Sounder (AIRS) instruments. This new generation of polar orbiting observing systems offers dramatic increases in geographic and spectral resolution. The MODIS instrument, which has been derived from AVHRR, offers 36 channels of 1-kilometer resolution data, of which 7 offer half-kilometer resolution data and two offer quarter-kilometer resolution data. The AIRS instrument will offer thousands of spectral channels of data that will allow high-resolution profiles of temperature and moisture to be generated. Terra is operational and has only had a few problems over the last two to three years, with switches back and forth to its A-side and B-side electronics. Both Aqua and Terra transmit the data via direct broadcast, with MODIS offered from both satellites, and Aqua also offering AIRS along with microwave and other instruments.

Other Satellite Systems







There are a host of other polar orbiting satellites that may offer some information, which could be of value to weather forecasting operations in the Antarctic, if they were available. Often the

data are not available, are costly to process, or are unable to be received. Some of those satellites with the country sponsoring them are:

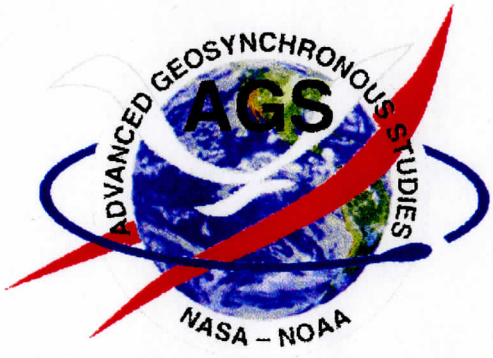
- Envisat: Launched March 1, 2002 (Europe)
- OceanSat-1 (IRS-P4): Oceanographic polar X-band system (India)
- Landsat-7: Earth resources satellite X-band system (NASA/USA)
- QuikScat: Scatterometer sensor satellite offering ocean surface derived winds (NASA/USA)
- ERS-1 and ERS-2: Synthetic Aperture Radar (SAR) X-band system (Europe)
- Radarsat: SAR X-band system (Canada)
- IRS: India polar orbiting satellite series (India)

This is not an exhaustive list, but offers reference to some other satellites that are in operation.

Upcoming Satellites

Geostationary

Geostationary Operational Environmental Satellite (GOES)



The next series of GOES satellites begins with launches in the middle of the first decade of 2000. This next series of satellites will be very much like the current series (similar instruments and still a 3-axis stabilized satellite), with some modifications for which channels and resolutions are available. Otherwise, this is the best-known launch schedule:

Platform	Launch Date
GOES-N	2/28/03
GOES-O	4/1/05
GOES-P	4/1/07
GOES-Q	4/1/08
GOES-R	4/1/12

It is important to the note that the GOES-R satellite will mark a significant change in this satellite series. GOES-R will be the platform for the Advanced Baseline Imager (ABI) and Advanced Baseline Sounder. These instruments are currently under development by NOAA.

Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) and Indian Ocean Meteorology and Oceanography (METOC) Imager (IOMI)

As a part of NASA's New Millennium Program, the Earth Observer 3 (EO-3) will host the first Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS). Due to be launched in October 2005, this hyperspectral sensor system will have a large array of sensors with the ability to have 32,600 sensors scan an area of about 317 square miles every ten seconds. The results of over 3000 spectral channels give this satellite over 60 megabytes of data transmitted every second to the ground (X-band system). This joint NASA, NOAA, and US Navy project plans to place the EO-3/GIFTS, after its first test period, over the Indian Ocean, as the US Navy's Indian Ocean Meteorology and Oceanography (METOC) Imager (IOMI). Developed by the Space Dynamics Laboratory at Utah State University and the Space Science and Engineering Center at the University of Wisconsin-Madison, GIFTS is expected to revolutionize spectral sensing of the Earth's atmosphere from space.

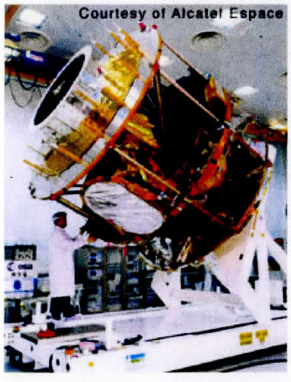
Feng Yun (FY-2/FY-4)

The Chinese geostationary satellite program expects to launch three more satellites in its current series and begin a new series in the future.

Platform	Launch Date
FY-2C	2003
FY-2D	2006
FY-2E	2009
FY-4	Unknown

It is expected that the rest of the FY-2 series will be a five-channel spinner satellite system, taking data in the visible, infrared and perhaps water vapor bands.

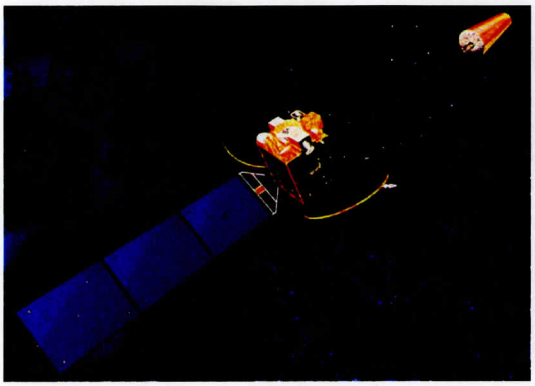
Meteosat Second Generation (MSG)

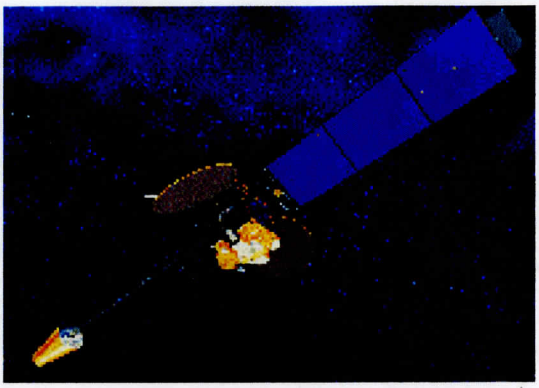


The European community has been actively planning the Meteosat Second Generation (MSG) satellite series. MSG-1 is due for launch in June or July of 2002 or later with operations not starting before the 2003. MSG-1 has had some problems with a launch vehicle. MSG-2 will be

launched in 2003, but it is unknown when it will be operational. The MSG series is a spinner satellite system that carries the Spinning Enhanced Visible and Infrared Imager (SEVIRI) 10-channel imager system. It is also expected to offer data encrypted except every six hours.

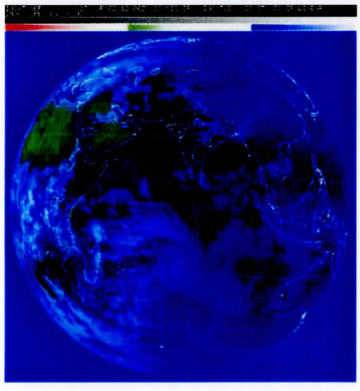
Multifunctional Transport Satellite (MTSAT)





The replacement satellite series for the Japanese GMS series is the Multifunctional Transport Satellite (MTSAT). This satellite system is built for both meteorological and communication applications. The first MTSAT-1 satellite unfortunately failed on launch. The replacement, MTSAT-1R is due to be launched in August or September 2003 with operations starting in December 2003. MTSAT-2 is due to be launched in June 2004 and might be placed in a 3-year standby operation until it is needed to replace MTSAT-1R. These satellites will be a 3-axis stabilized system carrying a 5-channel imager, which will have visible, infrared, and water vapor data.

INSAT

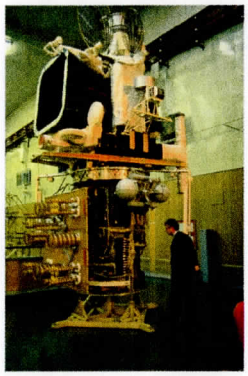


The next Indian INSAT series satellite to be launched is the INSAT-3D. This new satellite will carry a 6-channel imager and a 19-channel sounder very much like the GOES satellite system. At this time, it appears the data will remain encrypted. It is unclear if the US will work to navigate and calibrate the data retransmitted to NOAA. The next generation satellite system is called

METSAT. It is expected that this would be the first dedicate meteorological satellite system for India. The launches planned are:

Platform	Launch Date
INSAT-3D	2004
INSAT-4	Unknown
METSAT	Unknown

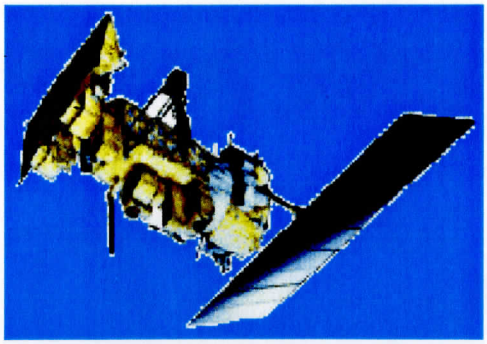
Geostationary Operational Meteorological Satellite (GOMS/Elektro)



It is expected that the Russian Federation will launch the GOMS-N2 satellite sometime in 2003. The 3-axis stabilized satellite will carry the Scanning Television Radiometer (STR) which will offer 3-channels of visible, infrared and water vapor data.

Polar Orbiting

Polar Orbiting Environmental Satellite (POES)

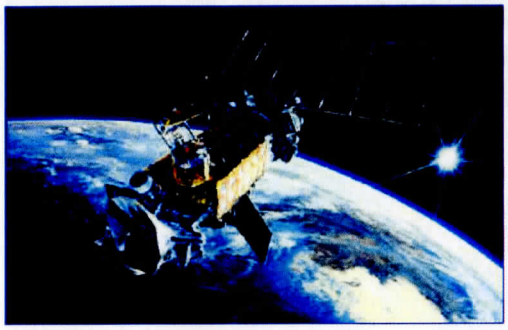


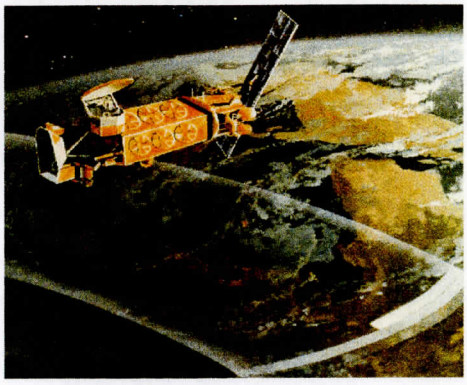
The POES series plans three more satellites, with one launched very recently. These satellites will carry the AVHRR imager, and an advanced sounding system. After the launch of NOAA-N',

the POES series of satellites will combine with the DMSP series to form a new national polar orbiting satellite series. It will also be combined with the new European polar orbiting program.

Platform	Launch Date
NOAA-M	6/24/02 (Successfully Launched - Mid-morning equatorial cross-time)
NOAA-N	6/01/04 (Afternoon equatorial cross-time)
NOAA-N'	3/01/08 (Afternoon equatorial cross-time)

Defense Meteorological Satellite Program (DMSP)

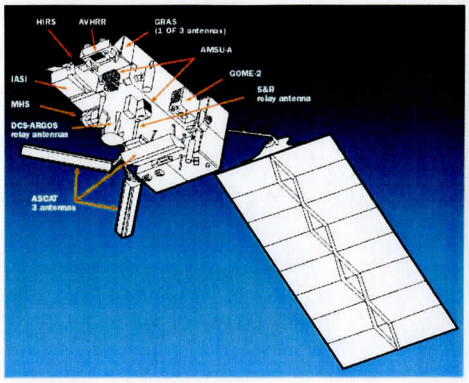


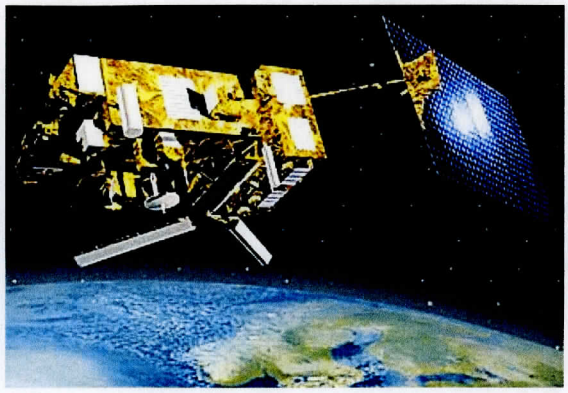


The DMSP program plans five more launches over the next several years. These series of satellites will offer the same or similar instruments and sensors, visible and infrared data as well as microwave data. After the launch of DMSP F-20, the DMSP series of satellites will combine with the POES series to form a new national polar orbiting satellite series. It will also be combined with the new European polar orbiting program.

Platform	Launch Date
DMSP F-16	10/1/02 - no earlier
DMSP F-17	1/1/03
DMSP F-18	2003
DMSP F-19	2005
DMSP F-20	2007

METOP

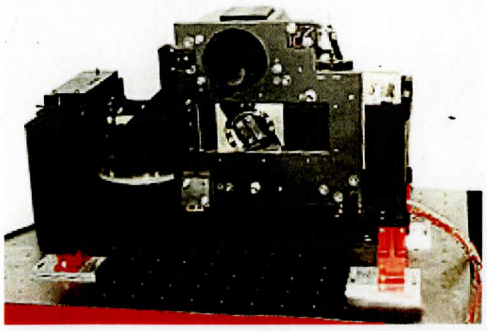




In a joint venture between EUMETSAT and the European Space Agency (ESA) and in collaboration with the new US national program, the European community plans to launch its first series of polar orbiting meteorological satellites, called METOP. The METOP satellite series will host many common instruments already on board POES and the new planned national polar orbiting satellites, including AVHRR, HIRS, etc. One concern with regard to accessing this platform over the Antarctic is data transmission encryption. EUMETSAT has not yet set a clear policy on whether METOP data will be encrypted over the Antarctic or not as of the writing of this report.

Platform	Launch Date
METOP-1	12/2005
METOP-2	2010
METOP-3	2014

National Polar-orbiting Operational Environmental Satellite System (NPOESS)



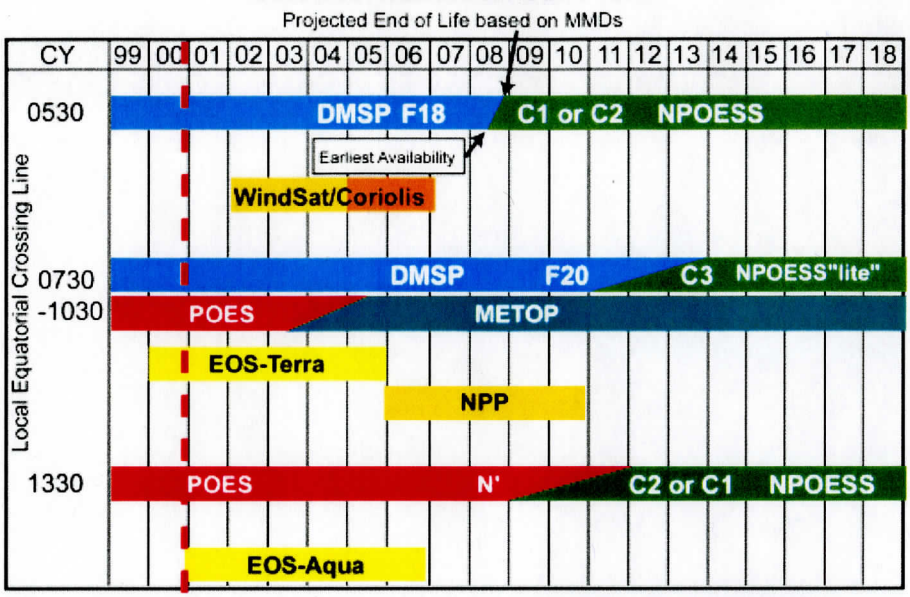
The US next generation polar orbiting meteorological observing platform is the National Polar-orbiting Operational Environmental Satellite System (NPOESS). A combining of prior US

civilian and military program, NPOESS aims to take polar orbiting observing into the next decade, with lessons learned from the DMSP, POES and EOS satellite systems. NPOESS will offer an advanced imaging system (Visible/Infrared Imager/Radiometer Suite (VIIRS)), a sounding system (Crosstrack Infrared Sounder—atmospheric moisture (CrIS)), and a microwave sounding system (Advanced Technology Microwave Sounder (ATMS)), among other instruments. One major concern for the Antarctic is that the imaging instrument currently planned for NPOESS does not have any partly absorptive channels, especially the water vapor channel. The author, on behalf of the USAP, has filed a formal request with the chair of the science committee that oversees the imager instrument to ask that a water vapor channel be added to the imager. Water vapor channel data, at high resolution, has not been available on polar orbiting platforms until the launch of the Terra satellite in the EOS satellite program. The NPOESS system is an X-band system, and will be a major change to those used to receiving the older POES and DMSP satellites that are L-band for data transmissions.

Platform	Launch Date
NPP	12/1/2005 or 3/1/2006
NPOESS-1	2009/2010
NPOESS-2	2011
NPOESS-3	2013
NPOESS-4	2015
NPOESS-5	2017
NPOESS-6	2018

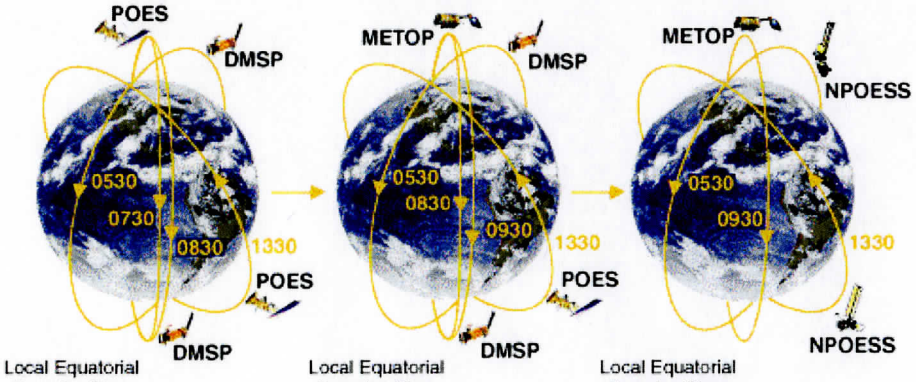
As an important aspect of this program, there are plans to launch an NPOESS Preparatory Project satellite, allowing all who are involved in polar orbiting meteorological satellites - users to developers - the chance to test out and learn about this new system. Below are two figures that depict the transition from the existing polar orbiter system in the US to the new national system, as well as the planned orbit configuration.

Satellite Transition Schedule



Evolution

U.S. civil defense programs, working in partnership with EUMETSAT, will ensure improved global coverage and long-term continuity of observations at less cost!



Today

- 4-Orbit System
  - 2 US Military
  - 2 US Civilian

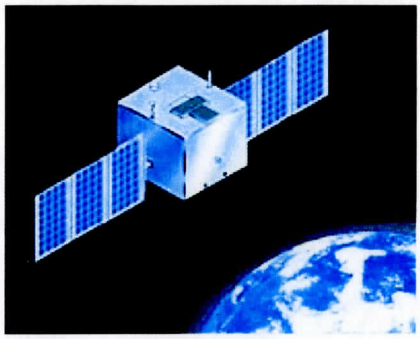
Tomorrow

- 4-Orbit System
  - 2 US Military
  - 1 US Civilian
  - 1 EUMETSAT/METOP

Future

- 3-Orbit System
  - 2 US Military
  - 1 EUMETSAT/METOP

Feng Yun 3 (FY-3)



The next generation polar orbiting satellite system from China is the FY-3 series. It is expected that this series of satellites will have improved imaging abilities, and that all of these satellites will be in morning equatorial cross-times.

Platform	Launch Date
FY-3A	2004
FY-3B	2006

Meteor

At this time, the Russian Federation has plans to launch one additional Meteor satellite METEOR-3M N2 in 2003. It is likely that this satellite will be launched in a sun-synchronous orbit with a morning equatorial cross time. As noted above, no additional non-sun-synchronous orbiting satellites are planned.

Other Polar Orbiting Satellites

Many other satellites are due to be launched over the next several years. Many of these listed below have some impacts on Antarctic meteorology, with regard to forecasting, observing and research. Here is the list of some of these satellites.

Global Positioning System/Meteorology Satellites (GPS/MET)

- Gravity Recovery and Climate (GRACE)- in orbit (United States/Germany/Russian Federation)
- Satelite de Aplicaciones Cientificas-C (SAC-C) - in orbit (Argentina/United States/Italy/France/Brazil)
- CHAllenging Minisatellite Payload (CHAMP) - in orbit (Germany)
- Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) - Launch date of 2005 (United States/Taiwan)

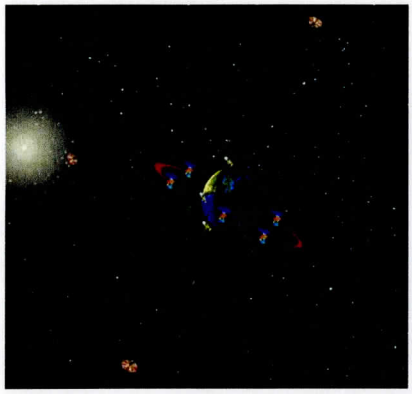
Currently, there are three satellites, SAC-C, CHAMP and GRACE, already on orbit that could offer the ability to profile temperature and moisture using the global position system instrumentation. A future and much more definitive satellite system to offer this ability is the COSMIC satellite series. These satellites will offer the ability to provide tens, if not hundreds of profiles of temperature and moisture around and over the Antarctic.

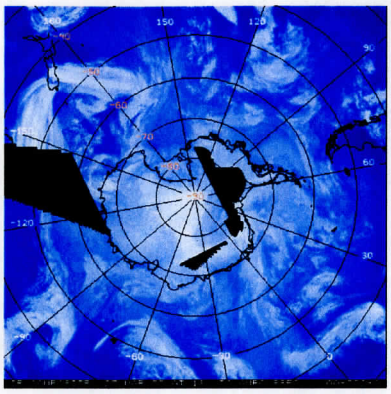
Other Satellites

- ICESAT - Launch date of 1/17/03 (United States)
- ADEOS-II - Launch date of 11/1/02 (Japan/United States - will carry new ARGOS system)
- CLOUDSAT - Launch date of 4/30/04 (United States/Canada)
- PICASSO-CENA - Launch date of 4/30/04 (France/United States)
- CALIPSO IIR - IR Imager (United States/France)
- Landsat Data Continuity Mission (LDCM) (United States)
- Aura (next EOS satellite also known as EOS-Chemistry) - Launch date of 1/1/04 (United States)

This is not an exhaustive list, but offers reference to some other satellites that are planned. It is interesting to note that several of these polar orbiting satellites are planned to fly in formation, specifically Aqua, Aura, CLOUDSAT and CALIPSO. Also CLOUDSAT and CALIPSO will be launched on the same rocket.

Polar Stationary



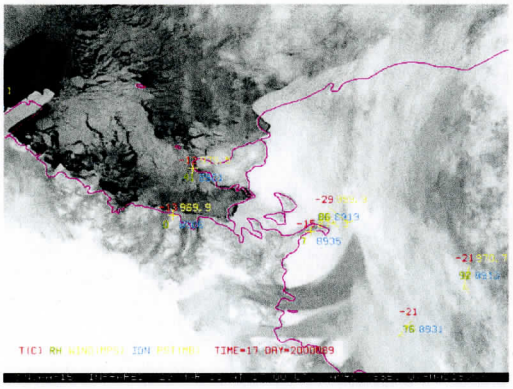


Meteorological satellites in other orbits are being considered and planned. The first satellite is Trianna, which is proposed to orbit between the Sun and Earth at the LaGrange 1 point. Trianna, which currently has a launch date of 5/1/2008, is in storage pending identification of launch flight/vehicle. Geostorm is another project (joint NOAA and United States Air Force) that proposes to place a solar sail into an orbit like Trianna that will have a mission of monitoring space weather.

Recently, NOAA has begun the investigation of placing a solar sail satellite into a polar stationary orbit (artificial LaGrange points), primarily for inter-satellite communications. Of course, this orbit offers the chance to image the Antarctic directly and often as well as give the opportunity to have improved communications (both inter-satellite and with the ground). Currently, the only solar sail activities, other than Geostorm, are private such as Team Encounter, which may be the first to launch demonstration satellites before the end of this decade. NOAA is working with Team Encounter on their engineering data, and is planning to report on its investigation in the near future.

Meteorological Satellite Usage in the USAP

Current Uses and Applications

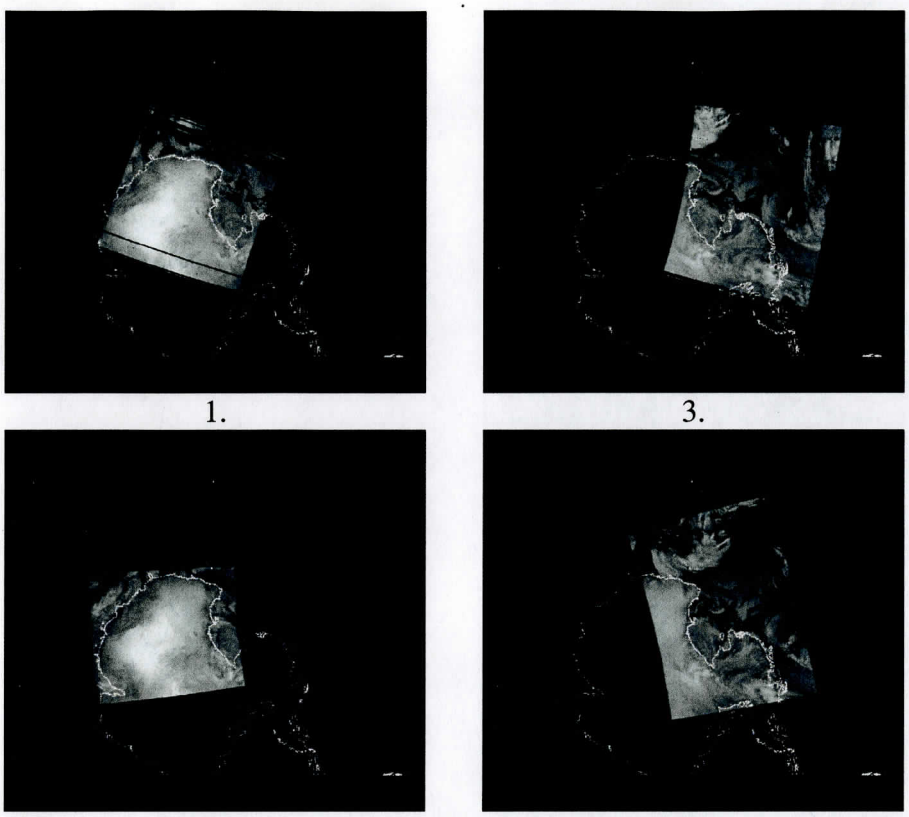


The USAP has used POES and DMSP satellite data for nearly 25 years. These satellites have been the staples for weather forecasting and research applications during this period. Beginning in 1992, the Antarctic composites generated at the University of Wisconsin offered a critical supplement. Additionally, the GMS satellite had been used for some years as yet another supplement to the mainstay polar orbiting satellites. The major use of the data from each of these sources has been limited to just viewing the imagery for weather forecasting applications. Some derived products have been utilized such as sea ice depiction, etc.

Current Limitations (Data Gap)

Data Gap Depiction

The biggest issue that affects the use of polar orbiting data for forecasting operations is the coverage limitations during the operational day at McMurdo Station, Antarctica, the headquarters for USAP forecasting activities. Below are four panel displays that depict the situation the forecasters face each day with the first and last usable data shown.



1. 3.

2. 4.

Figure 1. DMSP Data Gap Depiction: Image #1 is from 2107Z last helpful image, Image #2 is from 2249Z last pass, Image #3 is from 0605Z first pass (pretty good coverage) and Image #4 is from 0746Z first helpful image (Resulting in a 7 to 10 hour gap).

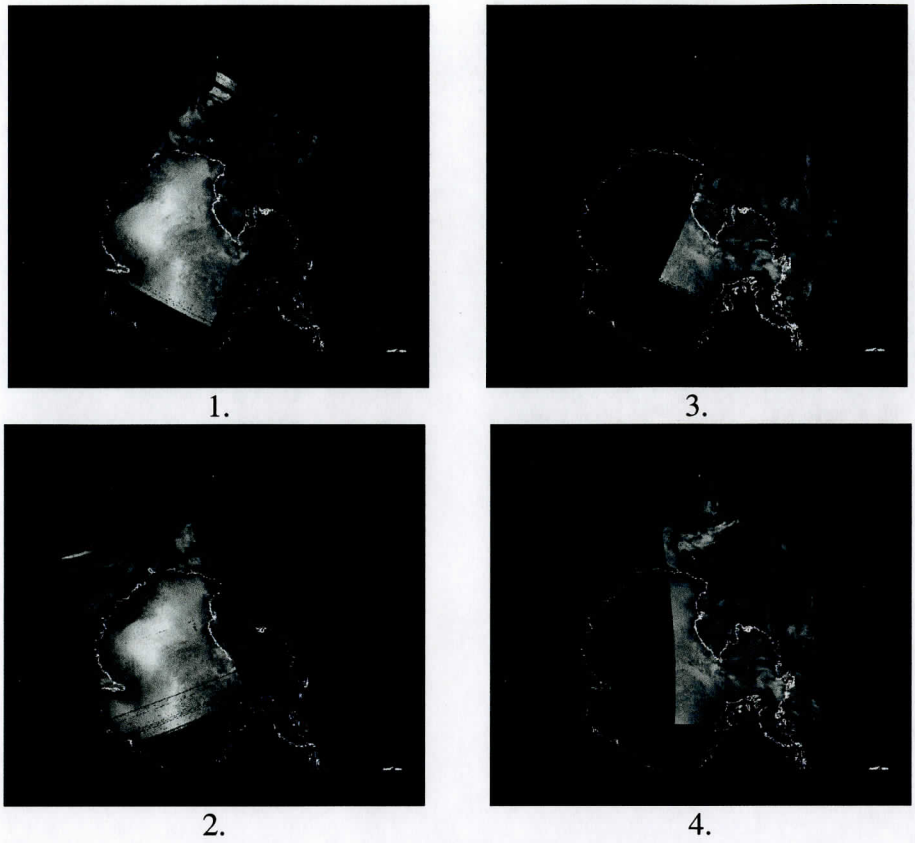


Figure 2. NOAA Data Gap Depiction: Image #1 is from 1759Z last helpful image, Image #2 is from 2121Z last pass, Image #3 is from 0107Z first pass and Image #4 is from 0248Z first helpful image (Resulting in a 3 to 9 hour gap).

Satellite Orbital Analysis During Data Gap: Over-flight Tracks

Below are depictions of several meteorological satellites and their over-flight tracks during the peak of data gap period from 20 UTC to 2 UTC from an example day. As can been seen visually, several satellites offer no coverage for McMurdo Station and the Ross Island/Ross Ice Shelf/Ross Sea region, including but not limited to NOAA, DMSP, FY-1C, or Meteor 3-5. There are some satellites that offer some help, such as Meteor 2-21 and 3-M, however they are not stable platforms or available at this time. Other satellites such as Terra and Oceansat-1 could offer some help, but are not available to forecasters in real-time at McMurdo Station at this time due to the lack of ability to receive and process data from these X-band satellites. Thus, SeaWiFS is the only platform that assists with this problem. It would appear with the preference (for a variety of climatological and operational reasons) for current and future polar orbiting satellites to be in fixed equatorial cross-times, there will be no polar orbiting solution available to close this data gap.

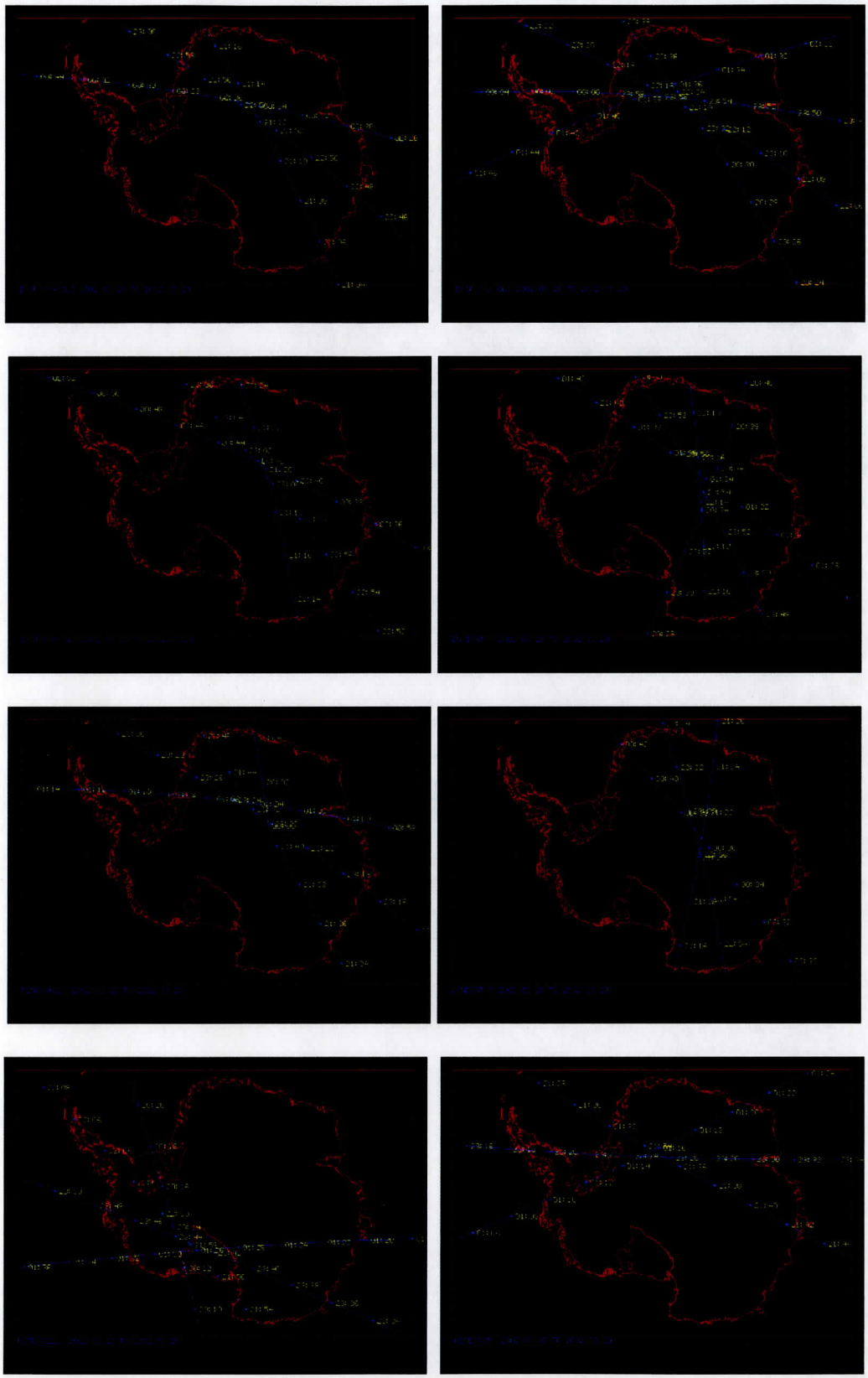


Figure 3a. Satellite over-flight tracks during the core of the data gap (20 UTC to 2 UTC daily) from DMSP F-12, DMSP F-13, DMSP F-14, Envisat, FY-1C, Landsat-7, Meteor 2-21 and Meteor 3-5.

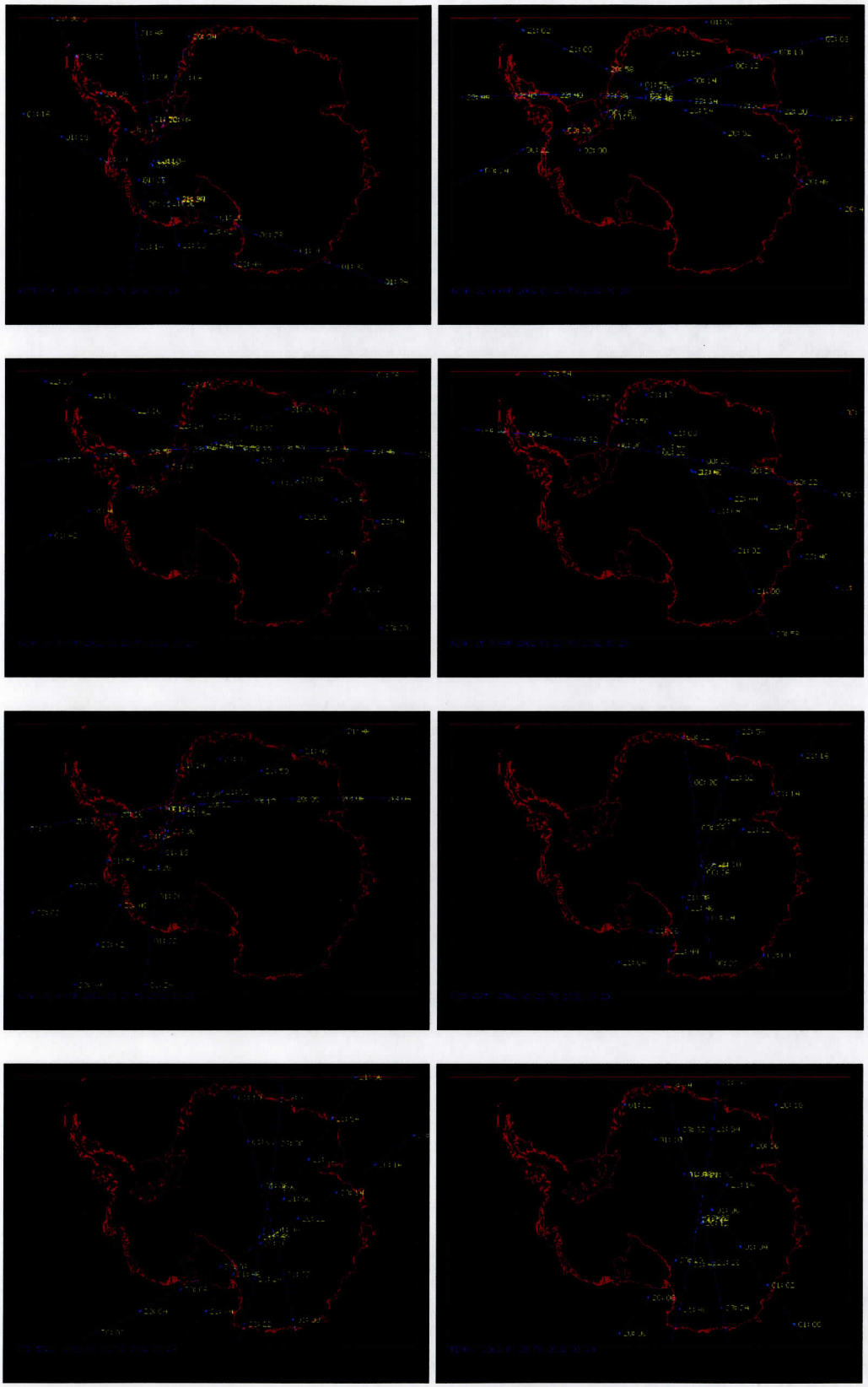


Figure 3b. Satellite over-flight tracks during the core of the data gap (20 UTC to 2 UTC daily) from Meteor 3-M, NOAA-12, NOAA-14, NOAA-15, NOAA-16, Oceansat, SeaWiFS, and Terra.

Potential Additional Applications for Forecasting

There are several applications of meteorological satellite data that could be put to use operationally that potentially offer the chance to aid and improve weather forecasting for the USAP. Only three will be discussed here, as there are many more that could and should be explored. One of the first applications that could be put into use is deriving satellite observed winds. Recently placed on the web, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) has a near real-time operational ability to compute winds from a series of consecutive NOAA AVHRR images. Soon this ability will be available from Terra MODIS imagery. These data will be of great value to the forecaster as well as input to the meso-scale numerical models run over the Antarctic in support of USAP operational forecasting activities. Another application is the possibility of being able to depict fog from satellite, giving forecasters aid with this number one aviation forecast problem. Finally, being able to put cloud detection products from satellite to use may be of equal importance to forecasters, pilots and numerical modelers alike. The ability to offer pilots, a depiction of where there are or are not clouds, with some level of confidence may be of significant value. Having meso-scale models correctly represent the cloud field allows for better forecasts of clouds and precipitation in the forecast. Overall, each of these example applications and others not mentioned might be a gateway into the next era of improved Antarctic forecasting.

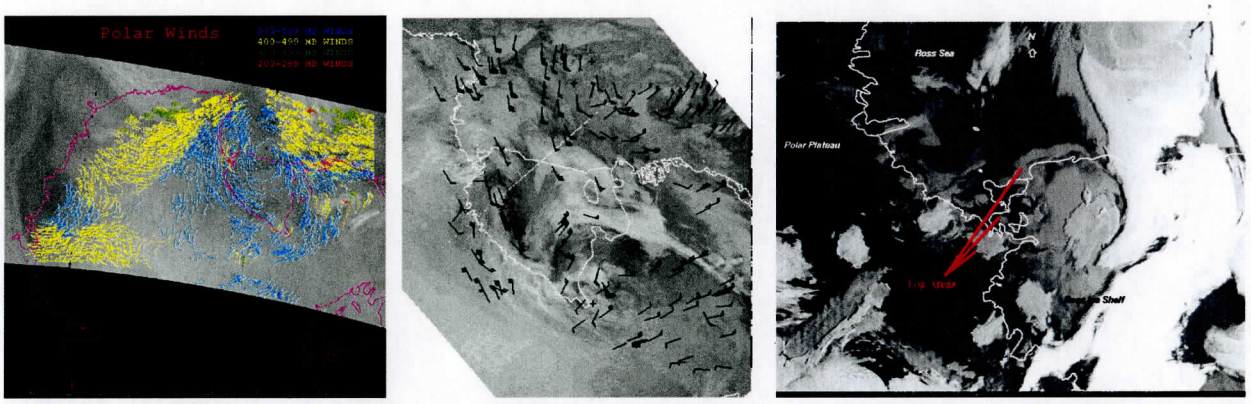


Figure 4a. Examples of water vapor winds and cloud drift winds (both from Terra MODIS) and a test fog product image from NOAA AVHRR centered over the Ross Sea region of Antarctica (left to right).

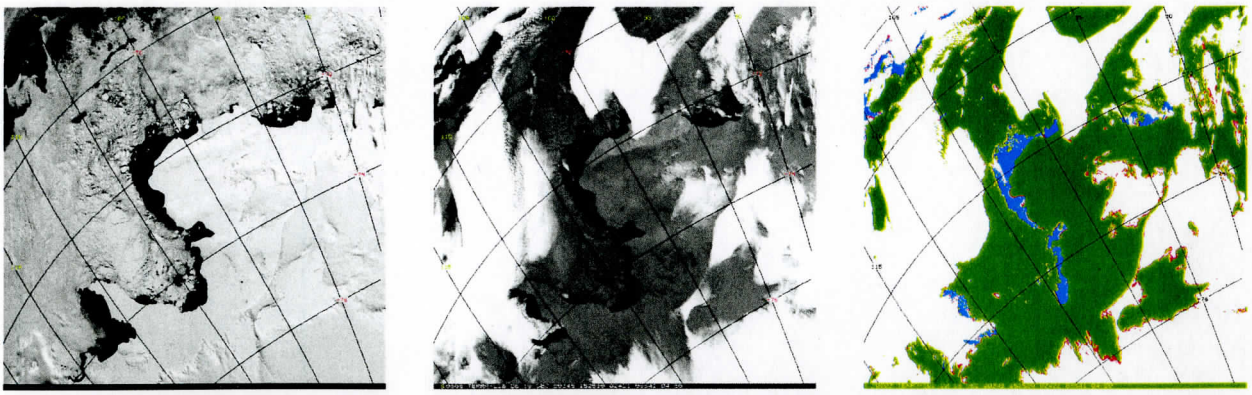


Figure 4b. Examples of two channels (visible and infrared) and the cloud product from the Terra MODIS over Pine Island Bay, Antarctica showing clear, cloudy and open water areas.

Potential Satellites to Benefit USAP Operations

It is clear that in the short run, the satellites that will likely benefit the USAP will be the next generation of polar orbiting satellites. This includes both research (e.g. Terra, Aqua, and NPP) and operational (e.g. NPOESS, and METOP) satellites. In the long run, the polar stationary satellite platform offers the most promise. Each of these satellite systems offers huge gains in capability in terms of improved spatial resolution, larger spectral depth and greater temporal coverage. These are the capabilities that will place Antarctic meteorology on equal footing with its mid-latitude counterpart.

Considerations and Limiting factors

There is no question that there are some issues that must be considered in facing the future of Antarctic operational satellite meteorology. Some of these limiting issues must be kept in mind for any future Antarctic meteorological satellite activities:

- Limited ground receiving abilities
- Processing on station
- High data volume
- Data gap
- Training/Education/Operational Integration
- Costs/Funding

Above all, the USAP needs to articulate its meteorological satellite needs to satellite operator agencies, including NOAA and NASA.

Summary

Several key issues from this report can be summarized as follows:

- Review of the status of current and future meteorological and meteorologically related satellites
- The USAP currently benefits greatly from meteorological satellites
- Over Antarctica, meteorological satellite data need to be put to increased use
- The USAP needs to review acquiring new data streams of satellite data (i.e. X-band polar orbiting platforms)
- The USAP needs to strongly consider the polar stationary satellite as a long-term solution to its meteorological satellite and possibly communications needs.
- The USAP must inform satellite-operating agencies such as NOAA and NASA of its support requirements for operations and research.

It is hoped that this report will serve to aid the USAP with these important issues.

References

This document was completely created using information available via Internet. In some cases, some of the information available, especially launch dates, is out of date or conflicts with other information. The author made the best assessment of the information and sources of information in compiling this report. Due to the diversity of information and time limitations, no explicit references have been made with the text. However, a list of some web sites is given below that were the sources for much of the information contained with in this report. It is important to note that this report, especially the future launch dates and status of operating satellite is subject to change, and that within three to six months the contents of this report in this respect are likely to be outdated.

United States Antarctic Program Meteorological/Satellite Data sites:

http://amrc.ssec.wisc.edu
http://arcane.ucsd.edu/
http://nsidc.org/usadcc/data_submissions.html

Japanese Meteorological Agency (JMA):

http://www.kishou.go.jp/english/index.html

Russian Federation:

http://sputnik.infospace.ru/
http://sputnik.infospace.ru/goms/engl/goms_e.htm

Chinese Meteorological Agency (CMA):

http://nsmc.cma.gov.cn/indexe.html

Australian Bureau of Meteorology:

http://www.bom.gov.au/
http://www.bom.gov.au/sat/MTSAT/MTSAT.shtml

United States/NOAA/NASA/others/etc.:

http://www.noaa.gov
http://www.nasa.gov
http://noaasis.noaa.gov/NOAASIS/ml/launch.html
http://www.ipo.noaa.gov
http://www.jpl.nasa.gov/calendar/calendar.html
http://rsd.gsfc.nasa.gov/goes
http://poes2.gsfc.nasa.gov/campaign/campaign_home.htm
http://liftoff.msfc.nasa.gov/RealTime/JTrack/3d/JTrack3d.html
http://fas.org/spp/index.html
http://www.teamencounter.com/

India Meteorological Department (IMD)/ Indian Space Research Organization (IRSO):

http://www.isro.org/
http://www.imd.ernet.in/

Europe/EUMETSAT/ESA:

http://www.eumetsat.de/
http://www.esa.int/