Antarctic Meteorological Satellite Report

For

SPAWAR Systems Center Charleston
Aviation Technical Services and Engineering Division (Code 67)

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Introduction

Meteorological satellites are perhaps the most critically important 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 current and future launch status of both operational and research meteorological satellites, with a focus on those impacting the Antarctic. It is an update to a report from 2002 entitled *Meteorological Satellite Status Report* (Lazzara, 2002). The current uses, limitations, and potential applications of meteorological satellites acquired by the United States Antarctic Program (USAP) are outlined. Meteorological satellites that are currently not available to the USAP are reviewed, including their applications, benefits, limiting factors and other miscellaneous considerations. Some important issues facing satellite meteorology are also discussed, especially with regards to data encryption and availability of frequencies for remote sensing.

Geostationary Satellites

Although geostationary satellites may not seem to be of great importance since the Antarctic region is on the limb of the field of view, they are indeed important. Most geostationary satellites do image the Southern Ocean and up to the coast of the Antarctic. Observations from geostationary platforms are a critical basis for satellite composites such as those generated by the Antarctic Meteorological Research Center (Lazzara et al. 2003a, and Lazzara et al. 2003b) because they show systems that will impact Antarctic weather. See Figure 1.

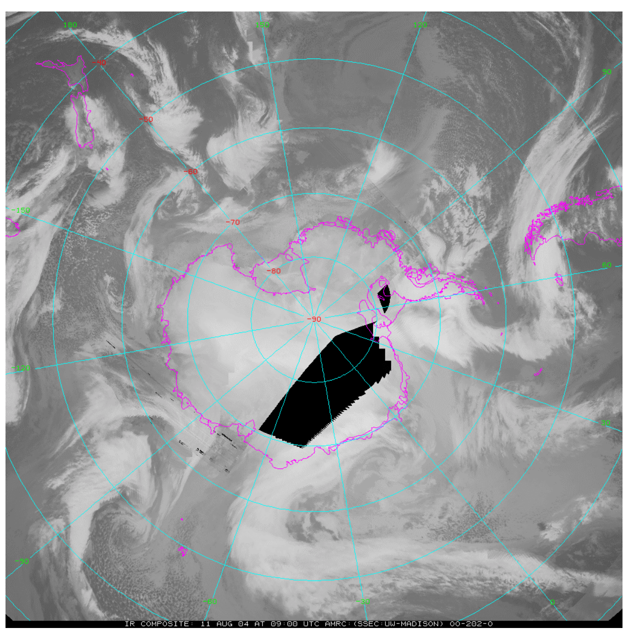
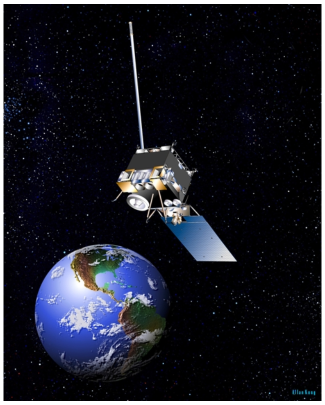
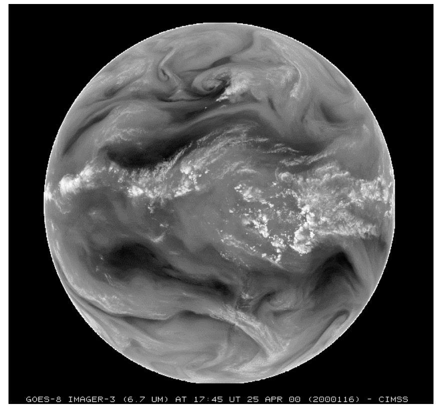


Figure 1. An infrared Antarctic composite satellite image combined from both geostationary and polar orbiting satellite platform observations. (*Courtesy of AMRC*)

Geostationary Operational Environmental Satellite (GOES)



Boeing



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The Geostationary Operational Environmental Satellite (GOES) program operated by the National Oceanic and Atmospheric Administration (NOAA), United States, currently has four satellites in orbit. GOES-10 (West – 135 degrees West) and GOES-12 (East – 75.1 degrees West) are the current operational satellites, with GOES-11 (155.8 degrees East) currently in on-orbit storage. GOES-11 is a fully functional satellite ready for use as a backup within 48 hours. GOES-11 will be taken out of storage in late 2004 for testing, but will be placed back in storage after the test. This past year, former East satellite, GOES-8, was decommissioned. GOES-9 (Pacific – 155 degrees East) satellite is on loan to the Japanese Meteorological Agency (JMA) from NOAA to assist with coverage over the Far East due to the end of the useful life of the GMS satellite and failure of the MTSAT-1 satellite launch (see GMS and MTSAT). Some of the problems that placed GOES-9 on storage, once recovered from storage and placed into use for Japan have not posed a significant problem. 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. The instruments on board include:

Sensors	**Description**
Imager	5 Channel imager
Sounder	19 Channel sounder
DCP	Data Collection Platform
SEM	Space Environment Monitor
SXRI	Solar X-Ray Imager (GOES-12 and beyond)

Built by Boeing, 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 (with a magnetometer added) 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:

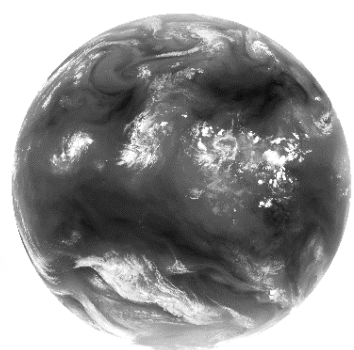
Platform	Launch Date
GOES-N	December 2004

GOES-O	July 2007
GOES-P	October 2008
GOES-Q	*Cancelled*
GOES-R	April 2012

It is important to 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 Hyperspectral Environmental Sounder (HES, formally called the Advanced Baseline Sounder or ABS). These instruments are currently under development by NOAA, with additional instrumentation planned, including a lightning mapper and coronograph. The launch of GOES-R offers the first chance that advanced soundings will cover the Southern Hemisphere (likely not the Antarctic itself), as well as having routine imaging to cover the Southern Hemisphere on a half-hourly or hourly basis since the pre-GOES-NEXT era (pre-GOES-8). As a minor note, the GOES low rate data transmission and distribution method, to comply with international agreement, has been moving away from the historical analog method (WEFAX) in favor of the new LRIT digital method (at 1691 MHz). GOES high rate data transmission and distribution or GVAR (GOES Variable) continues as before (at 1685.7 MHz)

Meteosat

EUMETSAT



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The Meteosat geostationary satellite program is overseen by EUMETSAT (Europe) with assistance from the European Space Agency. Currently, EUMETSAT is operating its older satellite series, Meteosat Operational Program (MOP), and its new Meteosat Second Generation (MSG). The oldest satellite, Meteosat-5 (INDOEX - 63 degrees East) continues an extended Indian Ocean Data Coverage (IODC). This satellite is beyond its life span and is starting to acquire an almost one-degree inclination. EUMETSAT plans to continue to operate this satellite at this location until 2005. Meteosat-6 is the in-orbit stand-by spacecraft and is located around 10 degrees East. It is noteworthy that the stand-by satellite is used for rapid scanning operations over Europe. Meteosat-7 is the operational spacecraft at a position of 0 degrees (since 3 June 1998). Meteosat-8 (3 degrees West - formally MSG-1) became operational on 29 January 2004. The dual operation of Meteosat-7 and Meteosat-8 will be completed at the end of calendar year 2005. EUMETSAT plans to have a two satellite configuration with a primary operational satellite and a backup spare satellite located near 0 degrees. IODC will likely continue after

2005, with the likely movement of the Meteosat-7 satellite to 63 degrees East, to have it take over for the aging Metosat-5 satellite. This satellite might also support a rapid scanning service, although it is unlikely this will impact the Antarctic region.

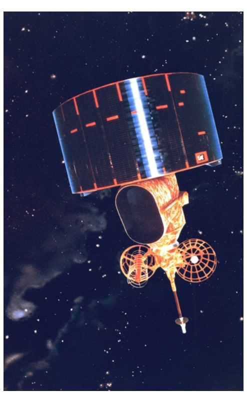
Platform	Launch Date
MSG-2	15 February 2005
MSG-3	2009
MSG-4	2012

All MOP satellites are spinner satellites offering visible, infrared and water vapor data. The MSG satellites are also a spinner satellite system that carries the Spinning Enhanced Visible and Infrared Imager (SEVIRI) 10-channel imager system. EUMETSAT also offers a rebroadcast service to its user community via commercial telecommunications satellites. Called EUMETCAST, Meteosat data, products and more are rebroadcast to the European community for a fee. The Hotbird satellite at 13 degrees East hosts the EUMETCAST service (11096 Mhz). IODC data will be provided via direct broadcast as well as via EUMETCAST.

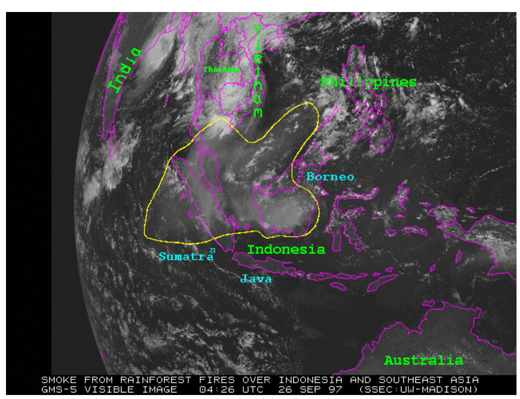
Sensors	Description
SEVIRI	Spinning Enhanced Visible and Infrared Imager (MSG satellites only)
MVIRI	Meteosat Visible and InfraRed Imager (MOP satellites only)

As with the GOES satellite series, the Meteosat satellites also offer a WEFAX service, with the older satellites (Meteosat-5, -6, and –7) offering analog transmissions (1691 and 1694.Z Mhz), and the new satellite (Meteosat-8) offering LRIT along with the full data service HRIT – however not directly from the satellite, but from EUMETCAST. The older satellites full data service is HRI (1691 and/or 1694.5 Mhz)

Geostationary Meteorological Satellite (GMS)



JMA



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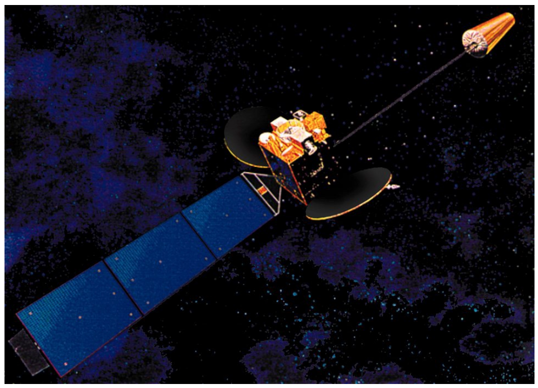
The Japanese Geostationary Meteorological Satellite (GMS), or Himawari, is the former geostationary satellite series overseen by the Japanese Meteorological Agency (JMA). The last satellite of the series stopped service on 22 May 2003. As noted above, NOAA has agreed to lend the JMA GOES-9 to fill a gap between the older GMS satellite series, and the upcoming launch of the new MTSAT satellite series (MTSAT-1 launch failed). The GMS satellite series was a spinning satellite series, offering visible, short wave and window infrared, and water vapor data during its operation. Currently the last satellite in the series, GMS-5 (140 degrees East), is retransmitting WEFAX (1691 Mhz) from the GOES-9 satellite, reformatted at the 140 degree East aspect for navigation, as the GOES-9 vantage point is from 155 degrees East.

Multifunctional Transport Satellite (MTSAT)



ABoM/JMA

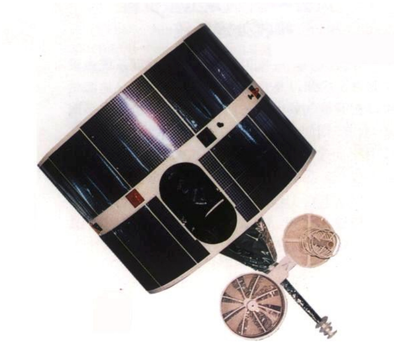
The replacement satellite series for the Japanese GMS series is the Multifunctional Transport Satellite (MTSAT). This satellite system is built for both meteorological and communication applications. The first MTSAT-1 satellite unfortunately failed on launch. The replacement is MTSAT-1R. The second satellite in the series MTSAT-2 will be placed in a standby mode until it is needed to replace MTSAT-1R. These satellites will be a 3-axis stabilized system carrying a 5-channel imager. This imager will have visible, infrared, and water vapor data (Channel Wavelength (μm) Visible (VIS) 0.55 - 0.90; Infrared 1 (IR1) 10.3 - 11.3; Infrared 2 (IR2) 11.5 - 12.5; Infrared 3 (IR3) 6.5 - 7.0; Infrared 4 (IR4) 3.5 - 4.0).

Platform	Launch Date
MTSAT-1R	2005 (As soon as the launch vehicle is ready per JMA/JAXA)
MTSAT-2	After MTSAT-1R

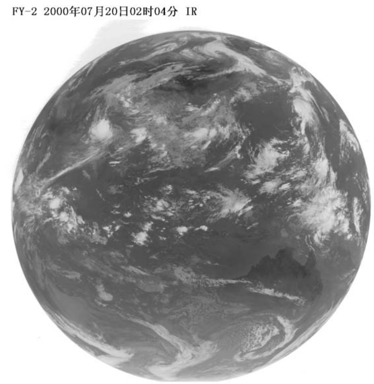
The new satellite will also support the LRIT transmission service, common to many current and all planned geostationary satellites, and may share the service with a WEFAX analog transmission service as well. It will also offer a full resolution service, HiRID (enhanced SVISSR)/HRIT.

Sensors	**Description**
S-VISSR	Stretched Visible Infrared Spin Scan Radiometer

Feng Yun (FY)



CMA



CMA

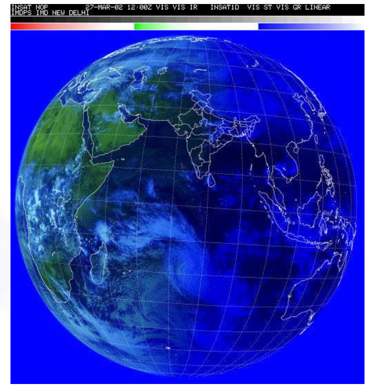
The Chinese geostationary satellite series, operated by the Chinese Meteorological Agency (CMA), is Feng Yun 2 (FY-2, Feng Yun means Wind and Cloud). The first satellite, FY-2A (FY-2 1R) launched on June 10, 1997, is of limited use due to de-spin subsystem problems and S-Band antenna problems and has been operated as only an experimental satellite. The operational satellite, FY-2B launched June 25, 2000, has been turned off for eclipse seasons (mainly in autumn and spring for roughly 90 days). For technical reasons there is no image transmissions covering the Southern Hemisphere. FY-2B is located at 105 degrees East and, like its experimental sister, is a three-channel (visible, infrared, and water vapor) spinner satellite. Full resolution data is transmitted at 1687.5 Mhz (S-VISSR) with future satellites to offer LRIT data. The Chinese geostationary satellite program expects to launch three more satellites in its current series and begin a new series in the future (FY-4). 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.

Sensors	**Description**
S-VISSR	Stretched Visible and Infrared Spin Scanning Radiometer

Platform	Launch Date
FY-2C	September 2004
FY-2D	2006
FY-2E	2009
FY-4	Unknown

INSAT

IMD


IMD

The India Meteorological Department (IMD) operates the INSAT series of geostationary satellites. These satellites are shared for meteorological and communications use. 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. The historical satellites include INSAT–1A, -1B, -1C, -1D, -2A, -2B, and -2E located at 74, 83, and 93.5 degrees East. There are two currently operational satellites: Kalpana-1 and INSAT-3A. Originally known as METSAT-1, Kalpana-1 was launched 12 September 2002 (74 degrees East). It was re-named in Feb 2003 after Kalpana Chawla, one of the seven-crew members of the Space Shuttle Columbia STS-107, first Indian-born woman in space. INSAT-3A was launched 10 April 2003. Both INSAT-3A and Kalpana-1 host the VHRR instrument, which is transmitted and encrypted at 2599 Mhz. In addition to the VHRR, Kalpana-1 also has a Charge Coupled Device (CCD) camera/payload with three channels in the visible and near infrared. All of the meteorological data from the INSAT satellites is encrypted. However, NOAA and IMD have made arrangements to share data. Unfortunately, the United States has not worked the navigation and calibration of the INSAT data at this time.

<u>**Sensors**</u>	<u>**Description**</u>
VHRR	Very High Resolution Radiometer
CCD	Charged Coupled Device

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. In addition, there is joint project planned with the French, named Megha-Tropiques, with three planned payloads with remote sensing in the short and long wave infrared as well as the microwave spectrums. The launches planned are:

Platform	Launch Date
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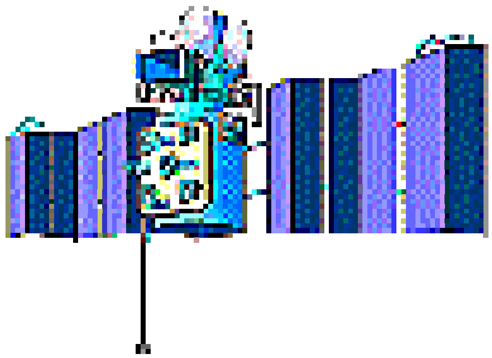
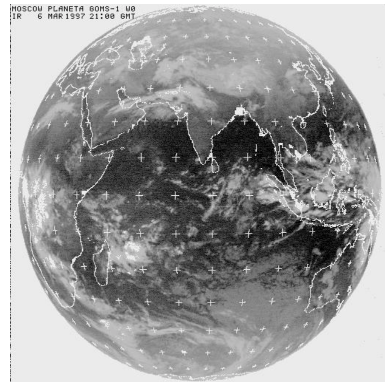
INSAT-3D	2006
Megha-Tropiques	2006

Global Operational Meteorological System (GOMS)



Planeta-C



Planeta-C

The Russian Planeta-C Meteorological Space System includes Elektro or the Global Operational Meteorological System (GOMS or GOMS-N1) that was launched 31 October 1994. GOMS went operational 1 June 1996 and broadcasts on 1691 MHz (WEFAX). It has provided very little imagery since it was launched and placed on orbit due to some operational issues. This three-axis stabilized satellite offers two channels - visible and infrared. It appears to have come to the end of its life in September 1998. It is expected that the Russian Federation will launch the GOMS-N2 satellite sometime in 2005. The three-axis stabilized satellite will carry the Scanning Television Radiometer (STR) which will offer three-channels of visible, infrared and water vapor data, and may carry other sensors as well. The new satellite will likely have HRIT and LRIT data formats.

Sensors	**Description**
STR	Scanning Television Radiometer

Platform	Launch Date
GOMS/Elektro 2	Late 2005
GOMS/Elektro 3	2010

Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS)

NASA

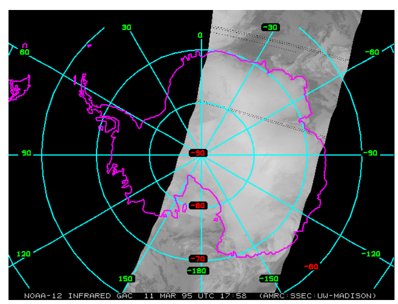
The Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) is an instrument set to go on the New Millennium Program (NMP) Earth Observing 3 (EO-3) geostationary satellite. GIFTS has 32,600 sensors to collect data, scanning an area of 512 kilometers square every ten seconds resulting in over 3000 spectral channels. The data rate is roughly 60 Megabytes per second, in the X-band for data transmission. This project is a joint partnership of NASA, NOAA and the US Navy. The instrument development is a joint effort by SSEC/UW-Madison and Space Dynamic Laboratory/Utah State University. The original plans called for the NASA EO-3 platform, after finishing the NMP mission for NASA, to be moved to the Eastern hemisphere for US Navy use. At such time, the satellite/sensor would have been subsequently renamed Indian Ocean Meteorology and Oceanography (METOC) Imager (IOMI).

As of the summer of 2004, NASA had in essence canceled the NMP EO-3. The US Navy continues to be a partner in the project despite the lack of spacecraft funding. NOAA is still funding the research and development effort, as it is a risk reduction effort for the GOES-R satellite. It does appear the instrument will still be built regardless of the lack of a spacecraft to put it on in the immediate future. Overall, GIFTS represents the future of remote sensing from space platform.

Polar Orbiting Satellites

Polar Operational Environmental Satellite (POES)

NOAA



UW-Madison/SSEC/AMRC

The US Polar Operational Environmental Satellite (POES) system operated by NOAA currently has five satellites in primary, backup, or standby mode. Currently, NOAA-16 and NOAA-17 are operational, with NOAA-15 in backup mode, and NOAA-12 and NOAA-14 in stand-by or limited use mode. NOAA-11 has recently been decommissioned as of 16 June 2004. NOAA-9, which was permanently deactivated some years ago and is tumbling freely, has a sporadic carrier on 137.5 Mhz (varies quickly according to orientation) and can cause interference to NOAA-12 and NOAA-15. This problem has not been reported recently as compared to the past several years.

NOAA-17, the most recently launch POES, has a mid-morning orbit with an approximate 10:30 am equatorial cross time. There have been some problems with the high-resolution picture transmission (HRPT - digital), causing the STX-3 to reduce power from 8 watts to 2.4 watts, resulting in reduced signal strength. NOAA-17 is transmitting Automatic Picture Transmission (APT - analog) on 137.62 Mhz and HRPT on 1707 Mhz. NOAA-16 has an afternoon orbit with an approximate 2 pm equatorial cross time. This satellite is fully functional, with the exception of the APT system, which failed a few months after launch. It is transmitting HRPT on 1698 Mhz. NOAA-15 has a morning orbit with an approximate 7:30 am equatorial cross time. This satellite is also functional. NOAA-15 also is transmitting direct broadcast data from its backup antenna system after a failure occurred with its primary system (APT on 137.5 Mhz and HRPT on 1702.5 Mhz). Recently NOAA-16, like NOAA-15 has had in the past, had problems with its imager, the Advanced Very High Resolution Radiometer (AVHRR), scan motor and the High resolution Infrared Radiation Sounder (HIRS).

NOAA-14, which has an older suite of satellite instrumentation, is in an afternoon orbit with an approximate 2 pm equatorial cross-time. It is functional, but its AVHRR unit scan motor has had problems much like NOAA-16 and NOAA-15, making the data unusable at times. NOAA engineers will no longer be making attempts to restart the scan motor on NOAA-14. NOAA-12 is in a morning orbit with a 6:40 am cross-time that is currently functioning well, with the exception of the sounding instruments. It did have a recent problem that forced the satellite into a safe-mode with the instruments turned off. NOAA operators have since turned back on the instrumentation, and the satellite continues to operate at this time. NOAA-12 operates APT on 137.5 Mhz and HRPT on 1698 Mhz.

The POES series plans two more satellites. These satellites will carry the AVHRR imager, and an advanced sounding system (both infrared and microwave). The NOAA-N' satellite will carry the next generation of Argos-III 2-way messaging capability for remote data collection systems, including Automatic Weather Stations (AWS). 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 (NPOESS).

NOAA-KLM series:

Sensors	**Description**
AVHRR	Advance Very High Resolution Radiometer
HIRS	High Resolution Infrared Radiation Sounder
AMSU-A	Advanced Microwave Scanning Unit-A (1 and 2)
AMSU-B	Advanced Microwave Scanning Unit-B
DCS	Data Collection System (Service Argos)
SEM	Space Environment Monitor
SARP/SARR	Search and Rescue Processor/Repeater

Platform	Launch Date
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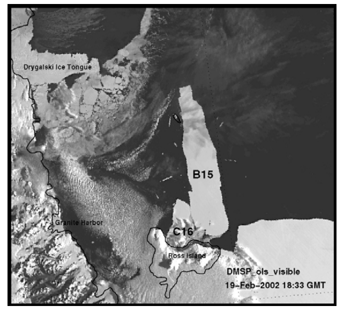
NOAA-N	11 February 2005 (Afternoon equatorial cross-time)
NOAA-N'	2008 (Afternoon equatorial cross-time: Launch date is pending on repairs)

Defense Meteorological Satellite Program (DMSP)

NGDC



RPSC

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-16, F-15, F-14, F-13, and F-12. All DMSP satellites have a morning equatorial crossing time orbit. These satellites offer a high-resolution imager of infrared and visible data (OLS instrument) and microwave imager and sounder data (SSM/I, SSM/T, & SSM/T2). Starting with the DMSP F-16 satellite, the new special sensor microwave imager/sounder (SSMIS) replaces the SSM/I, SSM/T, and SSM/T2 sensors, and will also be on future DMSP satellites.

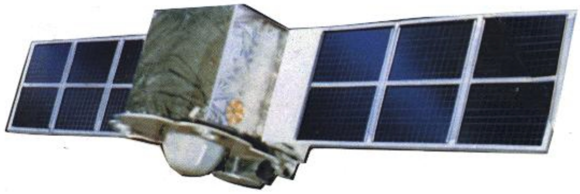
Sensors	**Description**
OLS	Operational Linescan System
SSM/I	Special Sensor Microwave Imager (F-15 and before)
SSM/T	Special Sensor Atmospheric Temperature Profiler (F-15 and before)
SSM/T2	Special Sensor Atmospheric Water Vapor Profiler (F-15 and before)
SSMIS	Special Sensor Microwave Imager/Sounder (F-16 and after)

There are other sensors on the DMSP satellites for space weather applications including: X-ray detectors, Ion spectrometers, precipitating electron detectors, etc.

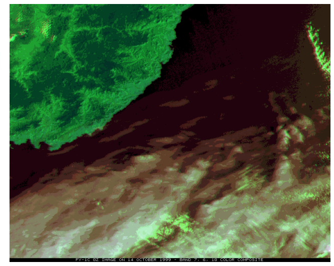
The DMSP program plans five more launches over the next several years. These series of satellites will offer the same or similar instruments and sensors, visible and infrared data as well as microwave data. After the launch of DMSP F-20, the DMSP series of satellites will combine with the POES series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

Platform	Launch Date
DMSP F-17	5 June 2005
DMSP F-18	October 2007
DMSP F-19	April 2009
DMSP F-20	October 2011

Feng Yun (FY)



CMA



UW-Madison/SSEC/CIMSS

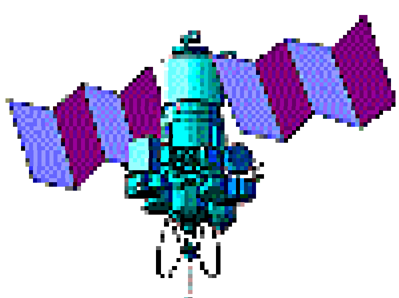
The Feng Yun (FY-1) is the operational polar orbiting satellite series operated by the Chinese Meteorological Agency for China. Currently, FY-1C and FY-1D are the operational satellites. The main instrument on the FY-1 series of satellite, a color HRPT (CHRPT), has 10 channels in the visible and infrared spectrum. Both FY-1 satellites transmit on 1700.4 Mhz, with the FY-1C satellite having a weaker signal. 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.

Sensors	**Description**
MVISR	Multichannel Visible and Infrared Scan Radiometer

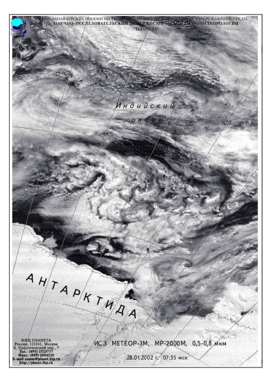
The next generation polar orbiting satellite system from China is the FY-3 series. It is expected that this series of satellites will have improved imaging abilities, and that all of these satellites will be in morning equatorial cross-times. In the meantime, one more of the existing generation of satellites will be launch along with China's second oceanographic satellite (HY-2) in the same rocket launch.

Platform	Launch Date
FY-1E	January 2005
FY-3A	2006
FY-3B	Unknown

Meteor



Planeta-C



Planeta-C

The Russian Federation operates the Meteor polar orbiting satellite system. Currently, there are no Meteor satellites operating. At this time, the Russian Federation has plans to launch one additional Meteor satellite Meteor-3M N2. It is likely that this satellite will be launched in a sun-synchronous orbit with a morning equatorial cross time. Meteor-3M N1 failed by December 2003 after all of its data transmitters failed.

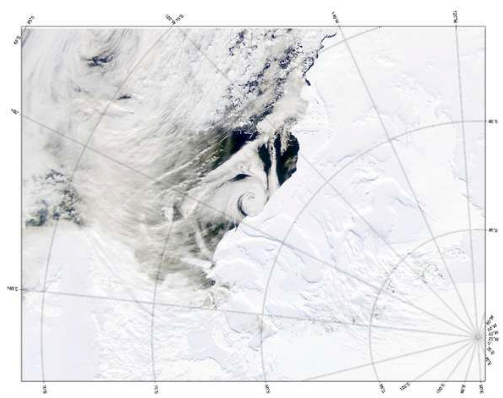
Sensors	**Description**
SAGE III	Stratospheric Aerosol and Gas Experiment (NASA Instrument)

Other instruments for infrared and visible scanning

Platform	Launch Date
Meteor-3M N2	2006

SeaStar

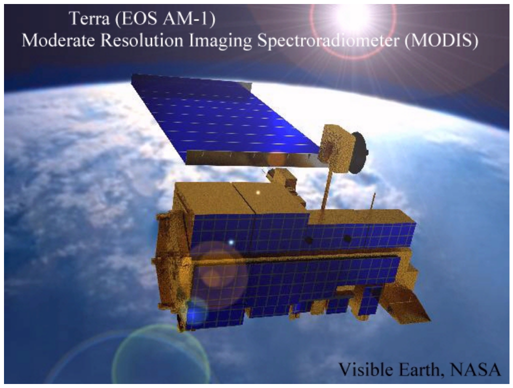
NASA



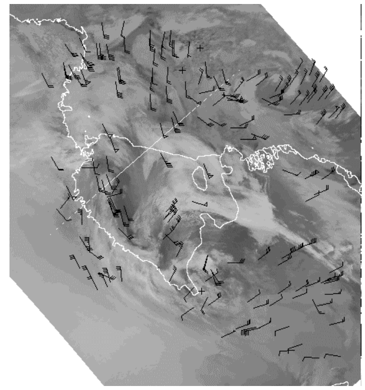
NASA

Orbital Science Corporation in conjunction with NASA operates the Orbview-2/SeaStar polar orbiting satellite, which has the SeaWiFS (Sea-viewing Wide Field-of-view Sensor) instrument (a Coastal Zone Color Scanner or CZCS) onboard. This satellite system is a joint NASA/private corporation effort. 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 offer a variety of visible channel data for ocean color applications as well as infrared data. Data are transmitted in an HRPT styled format at 1702.5 Mhz. No future satellites with the SeaWiFS/CZCS are planned.

Earth Observing System (EOS)



NASA



UW-Madison/SSEC/CIMSS

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; Aqua, launched on 4 April 2002; and Aura, just launched on 15 July 2004. Terra and Aqua offer direct broadcast data, while Aura does not. There are a host of other satellites considered a part of the EOS program, and they are reviewed in the "Other Polar Orbiting Satellites" section.

These flagship satellites offer a suite of instruments and sensor systems. 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 and is on the Terra and Aqua satellite, offers 36 channels of one-kilometer resolution data, of which seven offer half-kilometer resolution data, and two offer quarter-kilometer resolution data. The AIRS instrument, which has heritage from the HIRS instrument and is on the Aqua satellite, offers thousands of spectral channels of data that allow high-resolution profiles of temperature and moisture to be generated. The AIRS sensor, combined with the AMSU and HSB, gives a complete atmospheric profiling system. The AMSU is much like the AMSU-A on the NOAA satellites while the HSB is much like the AMSU-B on the NOAA satellites. The AMSR-E instrument is also on the Aqua satellite, and is a next generation microwave sensor.

Aqua:

Sensors	**Description**
MODIS	Moderate-resolution Imaging Spectroradiometer
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
AIRS	Atmospheric Infrared Sounder
AMSU	Advanced Microwave Sounding Unit
HSB	Humidity Sensor for Brazil
CERES	Clouds and the Earth's Radiant Energy System

Aura:

Sensors	**Description**
HiRDLS	High Resolution Dynamics Limb Sounder

MLS	Microwave Limb Sounder
OMI	Ozone Monitoring Instrument
TES	Tropospheric Emission Spectrometer

Terra:

Sensors	**Description**
MODIS	Moderate-resolution Imaging Spectroradiometer
MISR	Multi-angle Imaging SpectroRadiometer
MOPITT	Measurements of Pollution in the Troposphere
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CERES	Clouds and the Earth's Radiant Energy System

Terra is operational and has had a few problems over its five years of operation, but is currently operating nominally. It is nearing its end of life expectancy. Aqua is operational as well, and is also operating nominally. Aqua and Terra transmit data via direct broadcast, while Aura may not. Only the MODIS sensor is offered from the Terra satellite, while all sensors on Aqua are a part of the direct broadcast.

With the plans to install a dual X-band and L-band satellite system at McMurdo Station (Lazzara and Stearns, 2004), this will allow Terra and Aqua data for the first time be made available to the weather forecasters for real-time use.

EUMETSAT Polar System (EPS)

EUMETSAT

In a joint venture between EUMETSAT and the European Space Agency (ESA) and in collaboration with the new US national polar orbiting satellite 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, including AVHRR, HIRS, etc. In addition, a suite of European sensors will be onboard as well:

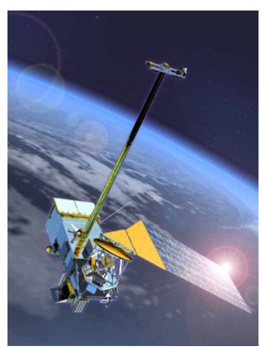
Sensors	**Description**
A/DCS	Advanced Data Collection System (also known as ARGOS)
AMSU-A1	Advanced Microwave Sounding Unit (USA)

AMSU-A2	Advanced Microwave Sounding Unit (USA)
ASCAT	Advanced SCATterometer (Europe)
AVHRR/3	Advance Very High Resolution Radiometer (USA)
GOME-2	Global Ozone Monitoring Experiment 2 (Europe)
GRAS	GNSS Receiver for Atmospheric Sounding (Europe)
HIRS/4	High Resolution Infra-Red Sounder (USA)
IASI	Infra-Red Atmospheric Sounder Interferometer (Europe)
MHS	Microwave Humidity Sounder (Europe)
SARP-3	Search And Rescue Processor (SARP-3)
SARR	Search And Rescue Repeater
SEM	Space Environment Monitor (USA)

One concern with regard to accessing this platform over the Antarctic is data transmission encryption (See section on Data Encryption).

Platform	Launch Date
METOP-1	December 2005
METOP-2	2010
METOP-3	2014

National Polar-orbiting Operational Environmental Satellite System (NPOESS)



IPO

The US next generation polar orbiting meteorological observing platform is the National Polar-orbiting Operational Environmental Satellite System (NPOESS). By combining prior US civilian and military programs, NPOESS aims to take polar orbiting observing into the next decade, with lessons learned from the DMSP, POES and EOS satellite systems (See Figure 2). 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. Water vapor channel data, at high resolution, had not been available on polar orbiting platforms until the launch of the Terra satellite in the EOS satellite program. It is expected that by the third NPOESS satellite a water vapor channel will be available. 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. However, it is important to note that the NPOESS system will offer an L-band (low rate data or LRD) direct broadcast service as well as an X-band (high rate data or HRD) direct broadcast service.

Sensors	**Description**
VIIRS	Visible/Infrared Imager/Radiometer Suite
CMIS	Conical Microwave Imager/Sounder
CrIS	Crosstrack Infrared Sounder
GPSOS	Global Positioning System Occultation Sensor
OMPS	Ozone Mapping and Profiler Suite
SESS	Space Environment Sensor Suite
APS	Aerosol Polarimeter Sensor
ATMS	Advanced Technology Microwave Sounder (NASA)
ADCS	Data Collection System (Service Argos)
ERBS	Earth Radiation Budget Sensor
SARSAT	Search and Rescue Satellite Aided Tracking
TSIS	Total Solar Irradiance Sensor
RADAR	Radar Altimeter

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 is a figure that depicts the transition from the existing polar orbiter system in the US to the new national system.

Platform	Launch Date
NPP	October 2006
NPOESS-1	2009
NPOESS-2	2011
NPOESS-3	2013
NPOESS-4	2015
NPOESS-5	2018
NPOESS-6	2019

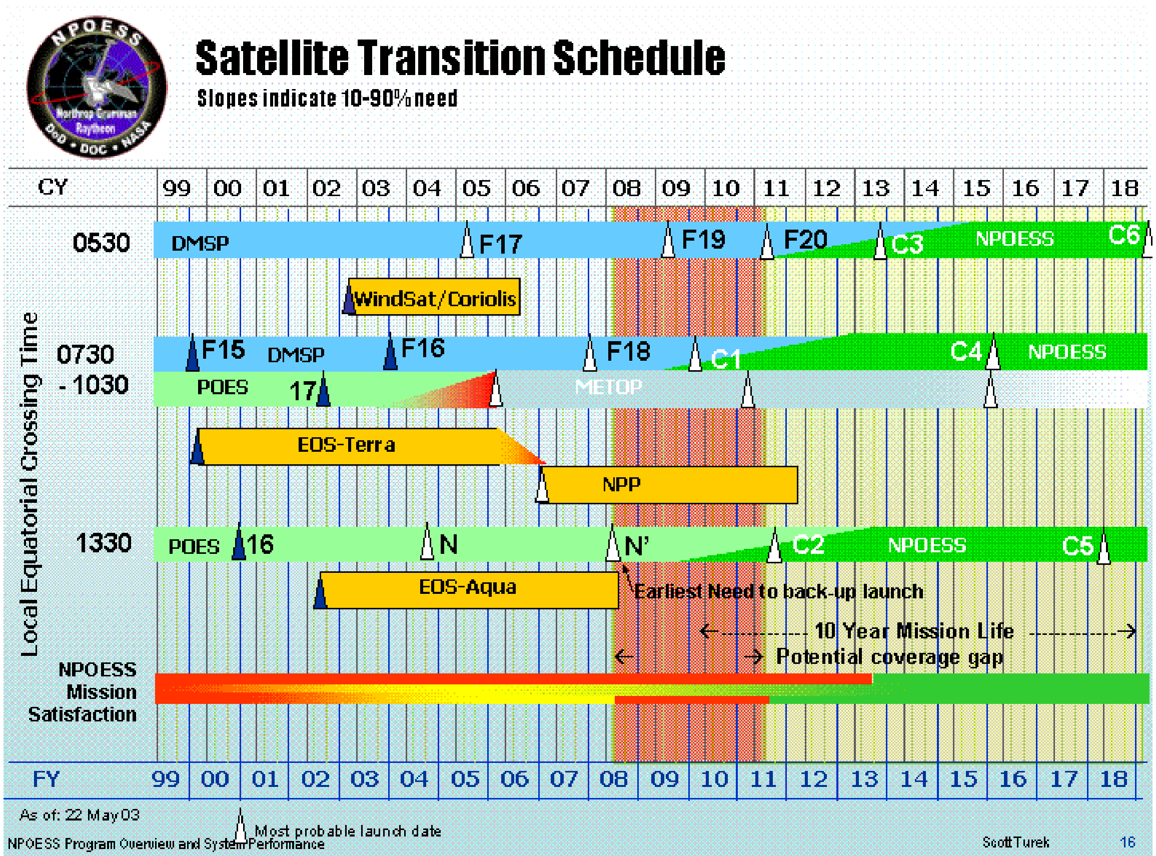


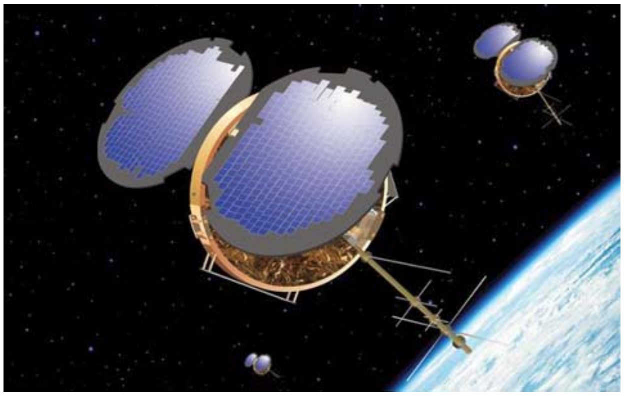
Figure 2. This table graphic depicts the transition from the NOAA/POES and DMSP era to the new NPOESS era (*Courtesy of Scott Turek/Raytheon*).

Other Polar Orbiting Satellites

NASA

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 in the categories of GPS/MET, Environmental and other noteworthy satellites systems.

Global Positioning System/Meteorology Satellites (GPS/MET)



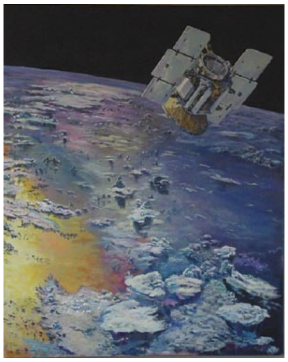
COSMIC

Currently, there are three satellites, SAC-C, CHAMP, and GRACE that are already in orbit that could offer the ability to profile temperature and moisture using the global positioning 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.

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

Platform	Launch Date
ROCSAT-3/COSMIC	2005

Other Environmental Satellite Systems



Colorado State University

There are a host of other polar orbiting satellites that may offer some information that could be of value to weather forecasting operations in the Antarctic. However, often the data are not available, costly to process, or unable to be received as a direct broadcast. Some of those satellites with the country sponsoring them are:

- Envisat: Launched 1 March 2002 with Advanced Synthetic Aperture Radar (ASAR), Medium Resolution Imaging Spectrometer (MERIS), Advanced Along-Track Scanning Radiometer (AATSR), Microwave Radiometer (MWR), etc. among other instruments (Europe/ESA)
- QuikScat: Launched 19 June 1999 Scatterometer sensor satellite offering ocean surface derived winds (NASA/USA)
- ERS-1 and ERS-2: Launched 17 July 1991 (ERS-1) and 21 April 1995 (ERS-2) Synthetic Aperture Radar (SAR) and Along-Track Scanning Radiometer (ATSR), Wind scatterometer, microwave sounder, GOME, etc. (Europe/ESA)
- Coriolis/WindSat: Polarimetric microwave radiometer Launched 6 January 2003 (IPO/USA)
- ICESAT: Launched 12 January 2003 with Geoscience Laser Altimeter System (GLAS) (NASA/USA)
- ADEOS-II: Launched 16 December 2002; Failed October 24, 2003 (Japan/USA/NASA – Carried new Argos/2 system in addition to a microwave radiometer (AMSR), a scatterometer (SeaWinds), an imager (GLI), a limb sounder (IILAS-II) and a polarimetric visible and infrared radiometer (POLDER))
- OceanSat-1 (IRS P4): Launched 26 May 1999 (India – Carrying Ocean Color Monitor (OCM) and a Multifrequency Scanning Microwave Radiometer (MSMR)).

This is not an exhaustive list, but offers reference to some other satellites that are in operation. Earth resource satellites such as Radarsat, Landsat, Spot, Resurs, etc. are left off of these lists due to the limited meteorological applications. Below is a selective list of satellites to be launched in the future. It is interesting to note that several of these polar orbiting satellites are planned to fly in formation, specifically Aqua, Aura, Cloudsat, Calipso, OCO, and PARASOL (See Figure 3). This planned formation has been dubbed the “A-Train.” Also CLOUDSAT and CALIPSO will be launched on the same rocket.

Platform	Launch Date
Sich 1-M (Ukraine)	15 October 2004
OceanSat-2 (India)	June 2005
Cloudsat (USA)	15 April 2005 (shared launch vehicle with CALIPSO)
CALIPSO (USA/France)	15 April 2005 (shared launch vehicle with Cloudsat)
PARASOL (France)	October 2004 (France)
Proba-2 (Europe/ESA)	Early 2006
SMOS (Europe/ESA)	2007
OCO (USA)	2007

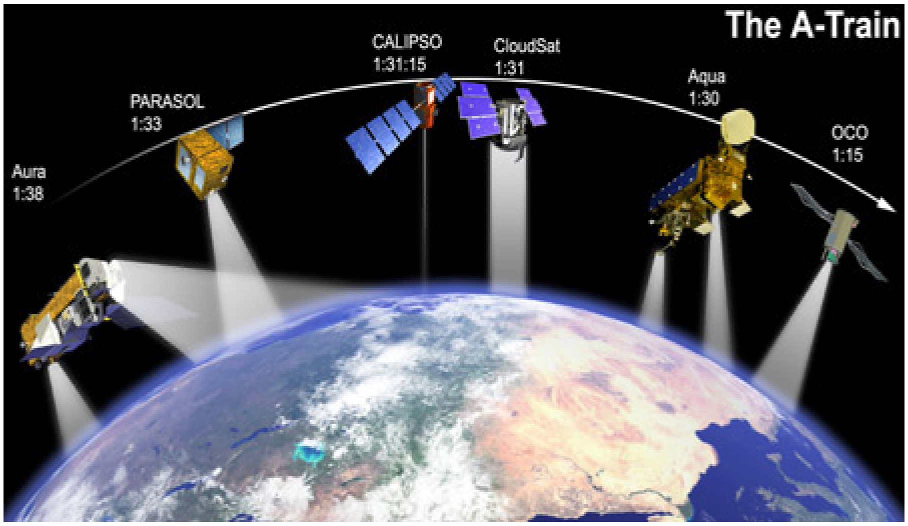
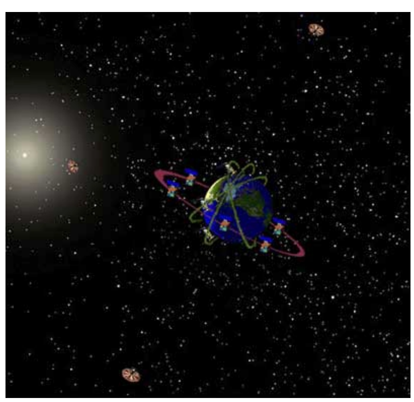


Figure 3. The near future will showcase a series of satellites flying in formation, also known as the A-Train (*Courtesy of NASA*).

Below is a listing of the key sensors that will be a part of the CloudSat, CALIPSO and PARASOL portion of the "A-train":

Sensors	Description
CPR	Cloud Profiling Radar (CloudSat)
CALIOP	Cloud Aerosol Lidar with Orthogonal Polarization (CALIPSO)
IIR	Imaging Infrared Radiometer (CALIPSO)
WFC	Wide-Field Camera (CALIPSO)
POLDER	Polarization and Directionality of the Earth's Reflectance (PARASOL)

Polar Stationary/Solar Sail



NOAA

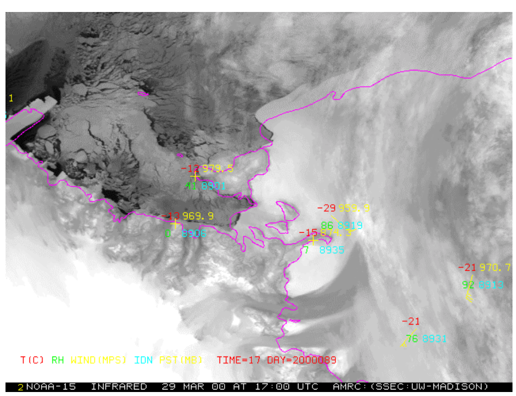
Meteorological satellites in other orbits are being considered and planned. One such satellite was to be Trianna, which was proposed to orbit between the Sun and Earth at the LaGrange 1 point. Trianna and its major sensor, EPIC, currently is in storage pending identification of launch flight/vehicle. Geostorm is another project (joint NOAA and United States Air Force) that had proposed to place a solar sail into an orbit that would 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 (McInnis and Mulligan, 2003). Of course, this orbit offers the exciting 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 most active solar sail activities are private efforts. One such example is Team Encounter. NOAA is working with Team Encounter on their engineering data, and is planning to report on its investigation in the near future. Other solar sail efforts are underway, including efforts in Germany, recent work in Japan and by the Planetary Society, which may be the first to launch a demonstration satellite, named COSMOS, before the end of this year launched from Russian submarine platform.

Platform	Launch Date
COSMOS	Late 2004
Team Encounter	November 2005

Meteorological Satellite Usage in the USAP

Current Uses and Applications



UW-Madison/SSEC/AMRC

The USAP has used POES and DMSP satellite data for over 25 years. These satellites have been the staples for weather forecasting and research applications during this period. It is worthwhile to emphasize the high importance and value that these two satellite platforms have to weather forecasting activities for the USAP. Beginning in 1992, the Antarctic composites generated at the University of Wisconsin offered a critical supplement. Additionally during the 1990s, the GMS satellite observations 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 (Lazzara et al. 2003a). Some derived products have been utilized (i.e. sea ice depiction). This is beginning to change, however, as the USAP is embarking on the beginning of a new era in Antarctic meteorology. The Antarctic Mesoscale Prediction System (AMPS) is making significant progress in Antarctic numerical weather prediction and is beginning to utilize satellite-derived observations (Jordan et al. pers. comms. 2004). The Antarctic Regional Interaction Meteorology Experiment (A-RIME – formerly the Ross Island Meteorology Experiment) has plans to begin its program in 2005, which will investigate a variety of Antarctic meteorological phenomena leading toward improved applications of satellite observations (Parish and Bromwich, 2002). Finally, the planned late 2004 installation of a dual X-and L-band satellite receiving system at McMurdo for joint operational and research use will be the means to acquire and apply advanced satellite observations for the benefit of both forecasters and researchers at the same time (Lazzara and Stearns, 2004).

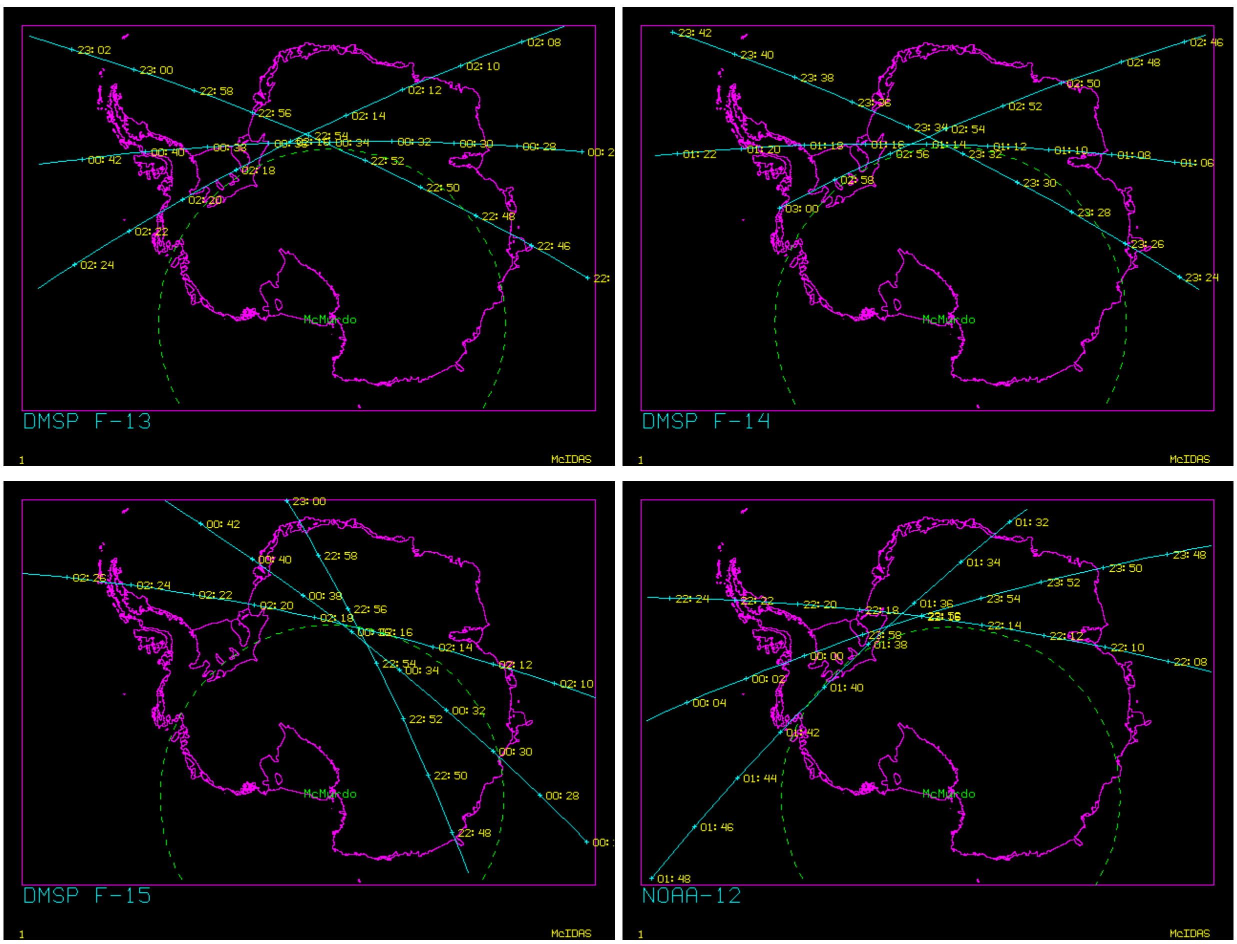
Current Limitations

The “Data Gap”

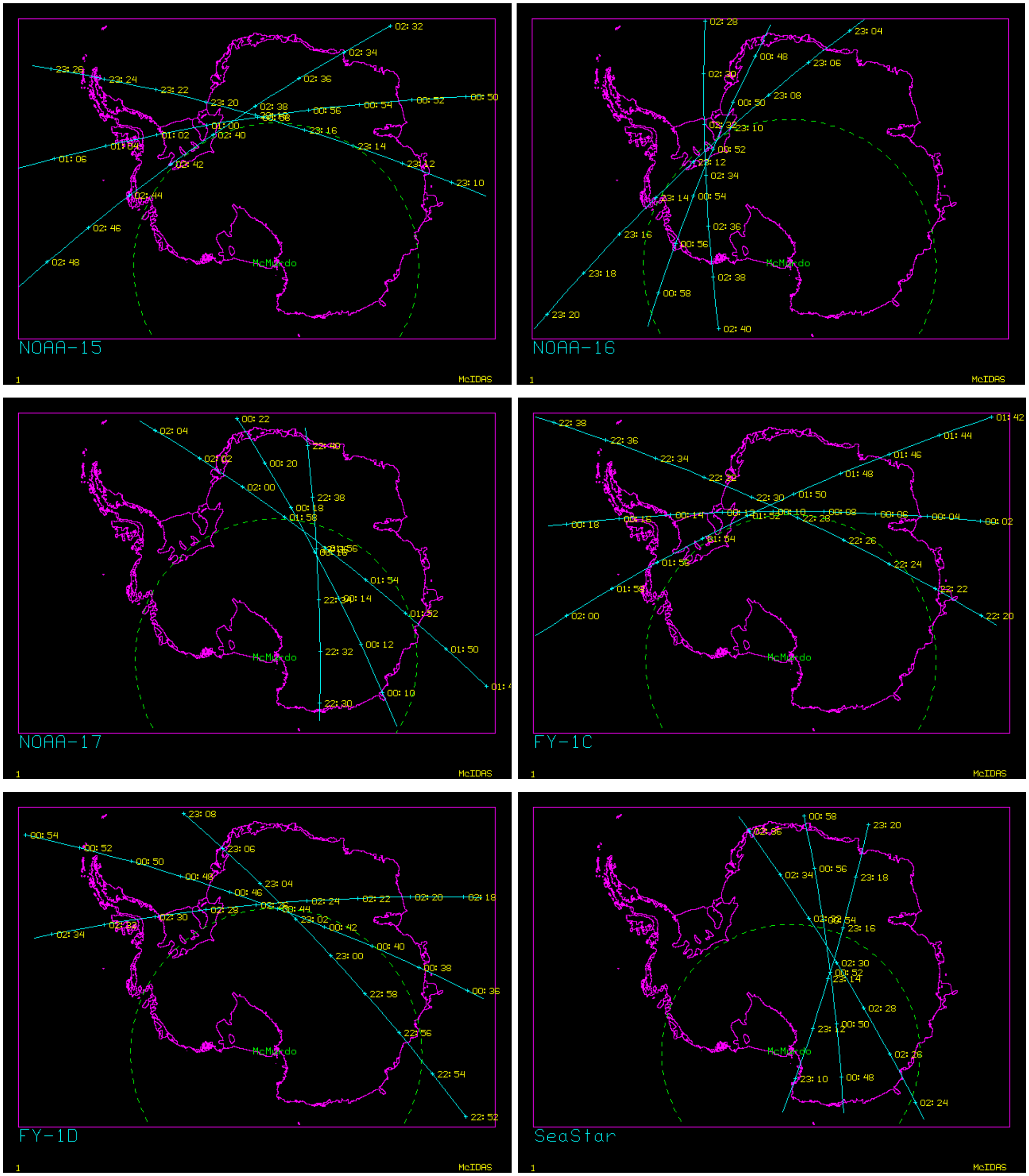
The biggest issue that affects the use of polar orbiting data for forecasting operations is the coverage limitations during the operational day at McMurdo Station, Antarctica, and the headquarters for USAP forecasting activities. Before the launch of NOAA-16 and NOAA-17, the orbital drift of older NOAA satellites and the limits of DMSP satellites to morning orbits only resulted in a significant gap in coverage over the McMurdo Station region, impacting weather forecasting operations at the nearby airfields for aircraft landing forecasts. Since the launch of the NOAA-16 and NOAA-17 satellites this gap has been reduced – likely as much as can be practically accomplished given the limitations placed on sun-synchronous polar orbiting slots for satellites as imposed by operators’ climatological, operational and operating/maintenance requirements. Use of other satellites (e.g. Aqua and Terra) in the future by the USAP with new X-band capabilities will allow the USAP to have more access to other satellites that could keep this gap at a minimum for the forecasting efforts.

Satellite Orbital Analysis: Over-flight Tracks

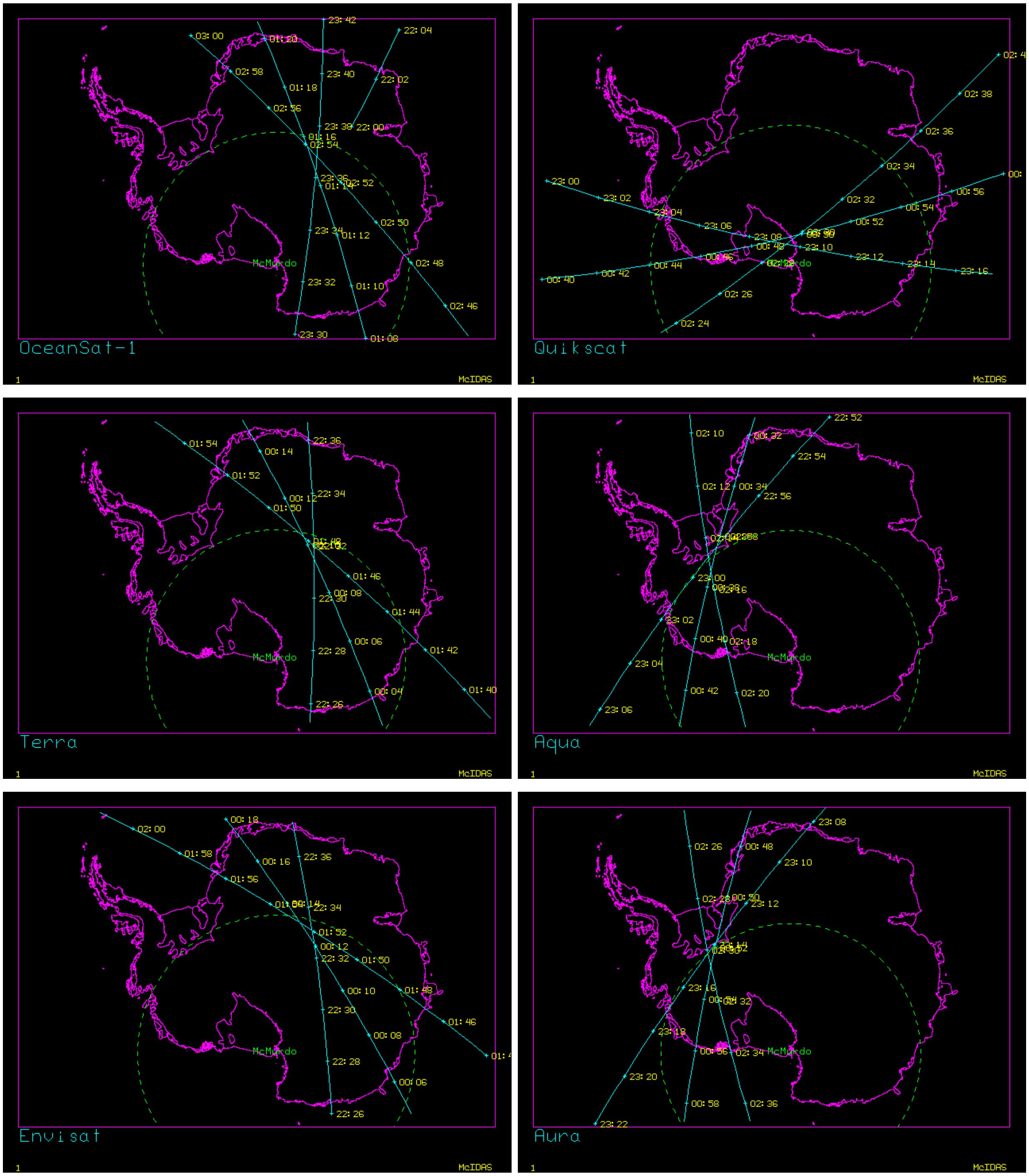
Below are depictions of several meteorological satellites and their over-flight tracks during the peak of the data gap period from 22 UTC to 3 UTC from an example day during WINFLY (25-26 August 2004). As can been seen visually, several satellites offer no coverage for McMurdo Station and the Ross Island/Ross Ice Shelf/Ross Sea region, including but not limited to DMSP F-13, DMSP F-14, NOAA-12, NOAA-15, FY-1C and FY-1D. There are some satellites that offer some help of varying degrees, such as DMSP F-15, NOAA-16, NOAA-17, OceanSat-1, Aqua, Terra, Envisat and Aura. Other satellites such as Quikscat offer the best help, but this platform does not offer the right sensors to benefit weather forecast operations (as well as the inability of McMurdo Station to receive this data and process it for science use in real-time on station). Thus the SeaStar (SeaWiFS) satellite is the only platform that assists with this problem. It would appear that due to the preference 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 completely. Given this, it is clear the launch and availability of NOAA-16 and NOAA-17 along with DMSP F-15 and SeaWiFS, all of which are available at McMurdo Station clearly have been of great help to forecasting efforts. The new Dual L-band/X-band satellite reception system will add Terra and Aqua overpasses which will support this effort. It is not clear that this new system will receive OceanSat-1 or Aura data (and Aura's sensor suite, even if it is directly broadcast, may not have the best sensors for forecasting operations). Envisat would offer some sensors of interest, however there maybe some issues with regards to processing, encryption, and permission that would need to be worked out with Envisat's operator (ESA) for this data stream to be used.



Panel 1. This first panel displays the orbital analysis for the DMSP F-13, F-14, F-15 and NOAA-12 (listed top to bottom, right to left) satellites during McMurdo's "data gap" period of 22 UTC to 3 UTC daily.



Panel 2. This panel displays the orbital analysis for the NOAA-15, NOAA-16, NOAA-15, FY-1C, FY-1D, and SeaStar (listed top to bottom, right to left) satellites during McMurdo's "data gap" period of 22 UTC to 3 UTC daily.



Panel 3. This panel displays the orbital analysis for the OceanSat-1, Quikscat, Terra, Aqua, Envisat and Aura (listed top to bottom, right to left) satellites during McMurdo's "data gap" period of 22 UTC to 3 UTC daily.

Potential Additional Forecasting Applications

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. Two classes of applications will be discussed: those for direct use by the forecaster, and those for direct use by numerical modelers, for indirect benefit of the forecaster. In many cases, the same product or application can benefit both classes at the same time.

Cloud Drift and Water Vapor Target Winds

One of the first applications that could be put into use is deriving satellite observed winds (See Figures 4 and 5). 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, Aqua, and Terra MODIS imagery. This data maybe of great value to the forecaster for flight forecasting as well as input to the mesoscale numerical models run over the Antarctic in support of USAP operational forecasting activities. With limited radiosonde launches around the Antarctic, these winds offer a significant increase in this class of observations. Plans for the 2004-2005 operational field season include making these datasets from Terra and Aqua MODIS data at least once or, if possible, twice per day from the new dual L-band/X-band system to be installed at McMurdo Station.

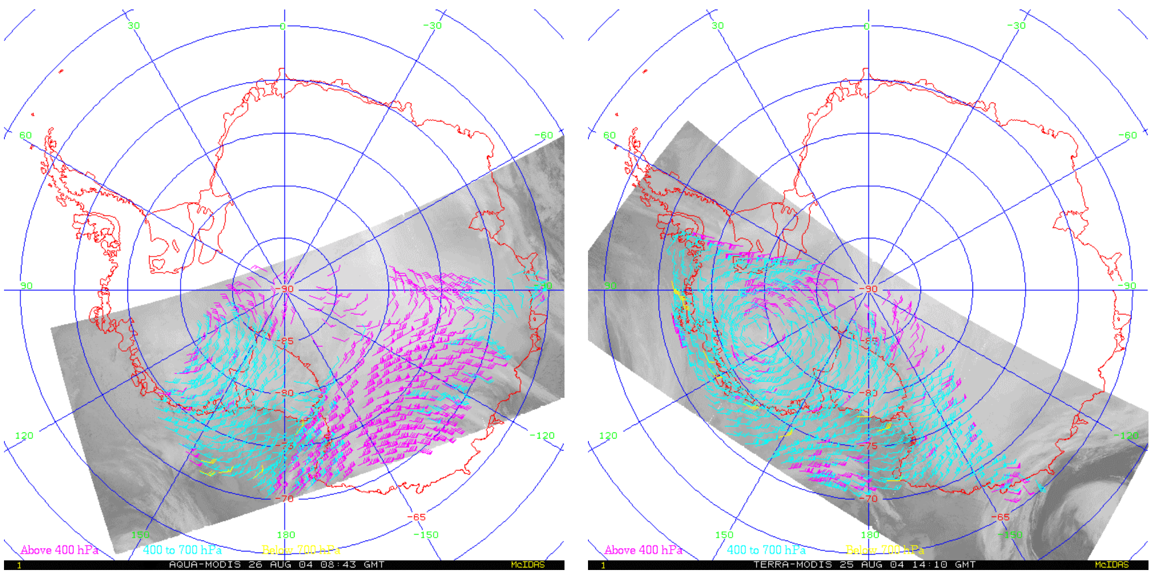


Figure 4. Sample cloud drift winds from Aqua (left) and Terra (right) depicting the wind regime over the Ross Ice Shelf region (*Courtesy of J. Key and CIMSS*).

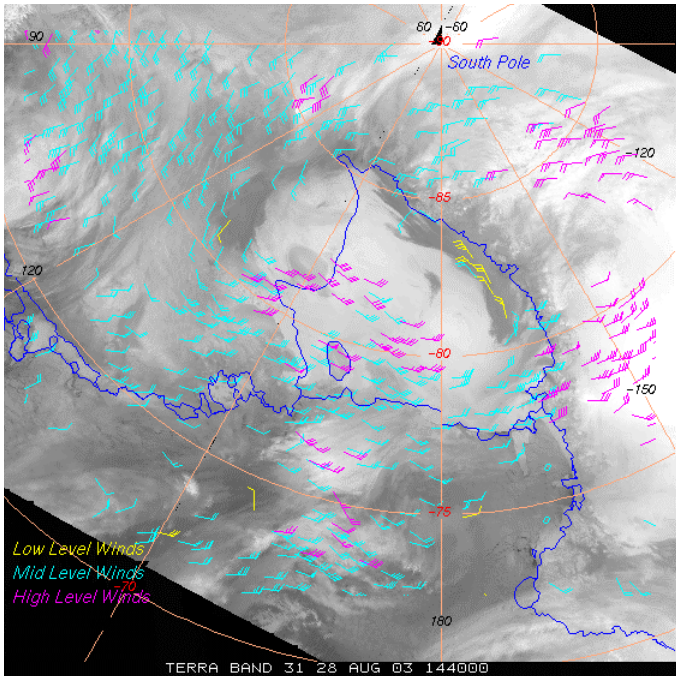


Figure 5. Another sample of satellite-derived winds, showing a closer view over the Ross Ice Shelf sector of the Antarctic (*Courtesy of J. Key and CIMSS*)

Cloud Detection and Cloud Properties

The ability to put cloud detection products from satellite to use may be of equal importance to forecasters, pilots, and numerical modelers alike (See Figure 6). The ability to offer pilots a depiction of where there are or are not clouds with some level of confidence is of significant value. Having mesoscale models correctly represent the cloud field allows for better forecasts of clouds and precipitation in the forecast.

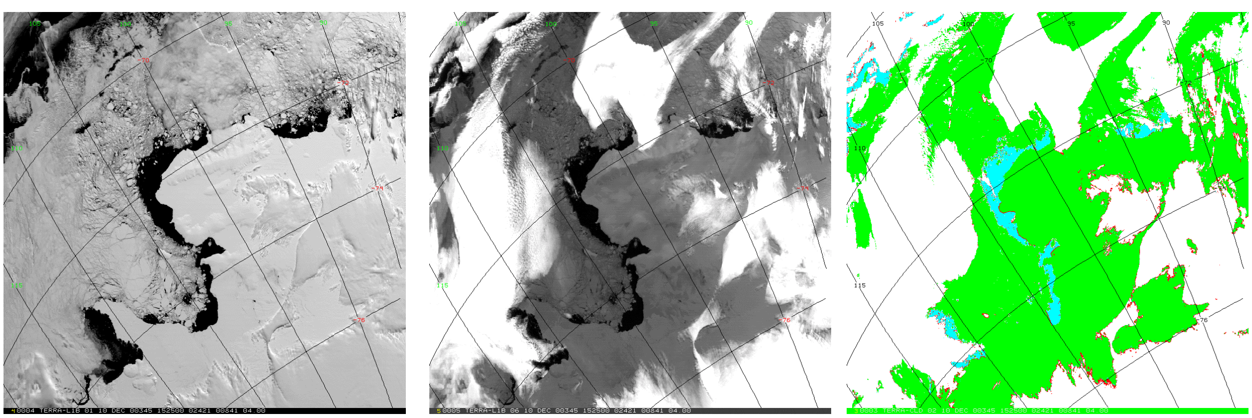


Figure 6. Examples of two channels (visible, left and infrared, center) and the cloud product (right) derived from the Terra MODIS over Pine Island Bay, Antarctica showing clear (green), cloudy (white), and perhaps open water areas (cyan) (*Courtesy of R. Frey and CIMSS*).

Additionally, cloud properties can also be derived from satellite sensing. Possible products include cloud top pressure, cloud phase, and total precipitable water content (See Figure 7). These products will likely have primary interest to numerical modelers, but may also be handy for forecasters, as forecast situations often call for this kind of information.

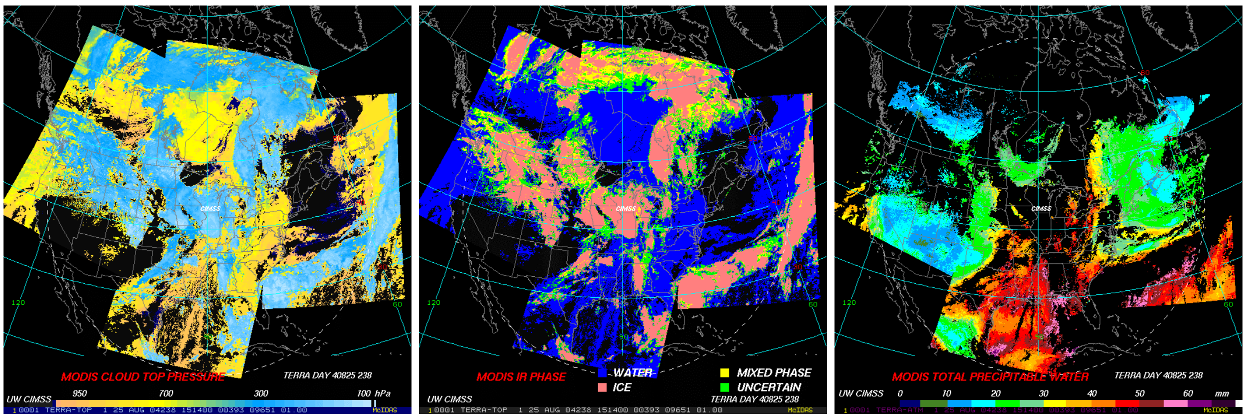


Figure 7. Examples of cloud top pressure (left), cloud phase (center), and total precipitable water (right) from Terra MODIS over the Continental United States taken at the University of Wisconsin Direct Broadcast system (*Courtesy of K. Strabala and CIMSS*). Colors of the display varing in meaning from product to product above.

Fog Detection

Another application is the possibility of being able to depict fog from satellite, giving forecasters aid with this number one aviation forecast problem. Efforts are currently underway to learn more about fog. It is too early to know if a fog detection method will be available from the research, but at the very least the improvement in enhancing and tracking fog may very well be possible from new satellite sensors such as MODIS over older sensors such as AVHRR.

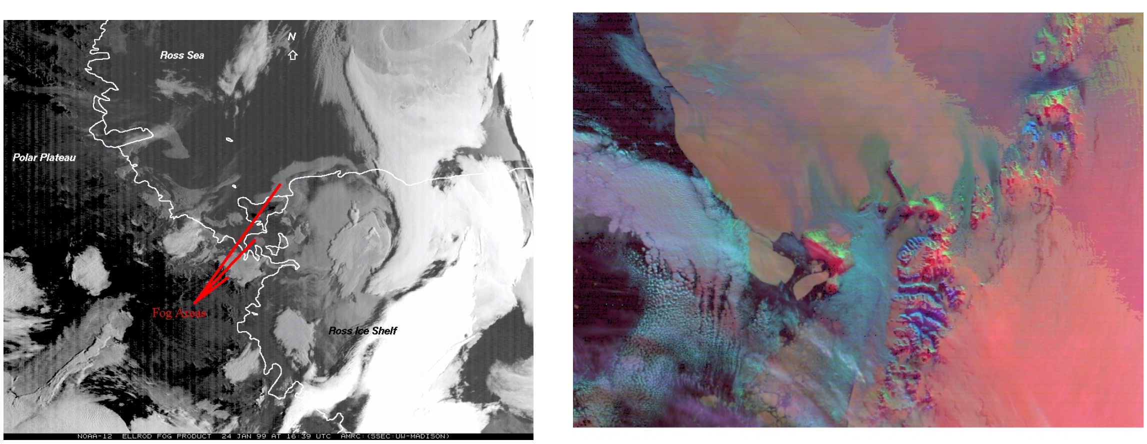


Figure 8. This display shows two separate example fogs over the Ross Island Region of Antarctica as seen on enhanced NOAA AVHRR (red pointers, left) and Terra MODIS (blue middle area, right) imagery. (*Courtesy of AMRC*)

Precipitation

A top problem for weather forecasters is precipitation. Microwave sensors are used in the middle and tropical latitudes to detect precipitation, and more specifically are used to estimate precipitation rates. Research on this topic in the Polar Regions faces some challenges and is in its infant stages. Efforts in this area are underway for the Antarctic, and future results may offer improved information on precipitation to forecasters.

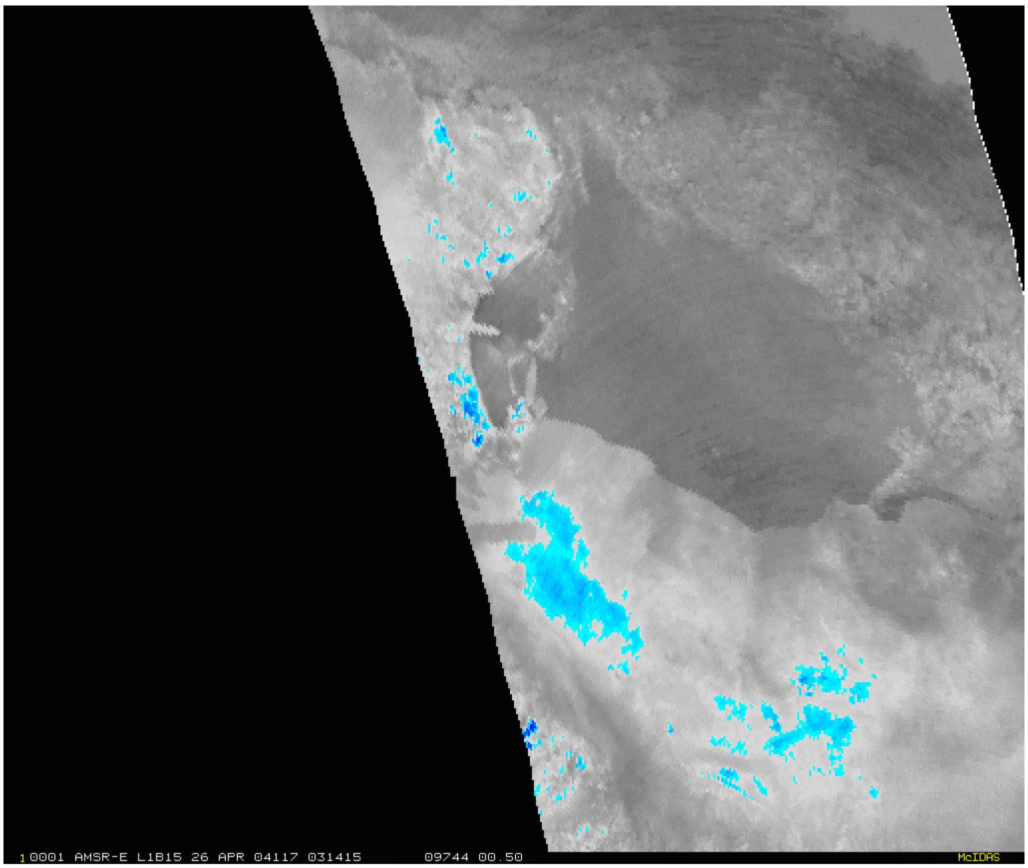


Figure 9. An example AMSR-E image over the Ross Sea and Ross Ice Shelf region of Antarctica with colder brightness temperatures enhanced in blue. Microwave information may be utilized in the future to assist with precipitation determinations (*Courtesy of S. Knuth*)

Profiles of Temperature and Moisture

A product that may benefit both the numerical modeling efforts and forecasters are the profiles of temperature and moisture from the sounder sensors available on some satellite platforms. The NOAA satellites offer the HIRS and AMSU sensors – together making up the ATOVS system. On the Aqua satellite, the combination of the AIRS, AMSU, and HSB sensors allow for the retrieval of vertical profiles of temperature and moisture. With limited radiosonde soundings around the Antarctic, the use of the satellite for this information over much more of the Antarctic may provide key information. Efforts are underway now to employ ATOVS retrievals in the Antarctic Mesoscale Prediction system (joint project with AMRC/CIMSS and NCAR/MMM). With the future availability of direct broadcast data from Aqua, additional high-resolution profiles from the several thousand-channel AIRS sensor may provide improved profiles beyond the ATOVS system (See Figure 10). In any case, both systems offer information that is currently under-utilized in the forecasting arena. In addition, in the near future as a compliment to these systems, COSMIC will start to come on-line and offer profiles as well. The combination of the two may prove to be powerful information throughout the Antarctic and adjacent waters region.

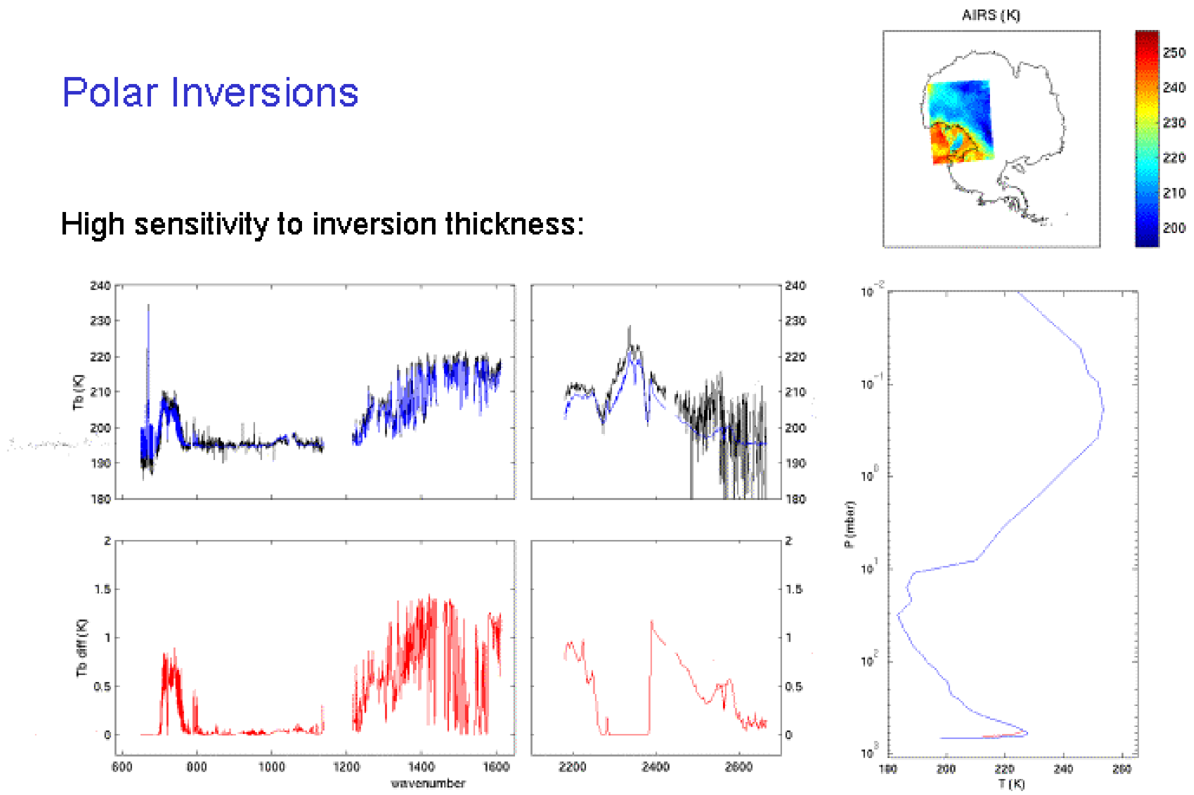


Figure 10. Sample displays of spectra, profile, and image from the AIRS instrument on Aqua (*Courtesy of David Tobin*)

Sea Ice Depiction and Iceberg Monitoring

Sea ice and icebergs can pose problems for USAP shipping interests - both supply and research vessels. Since the 2001-2002 field season, the icebergs outside McMurdo Sound have changed the sea ice dynamics and ocean current flow in the Western Ross Sea. Hence, now more than ever, sea ice and iceberg monitoring has become an important concern for ship routing and forecasting. Existing sensors such as the SSM/I on the DMSP (see Figure 11) satellite system as well as new sensors on the research satellites, such as AMRS-E on Aqua, offer improved monitoring. In addition to microwave sensors, SAR and scatterometer sensor capabilities offer an all weather means to monitor sea ice, although these datasets are not always available in real-time to USAP forecasters.

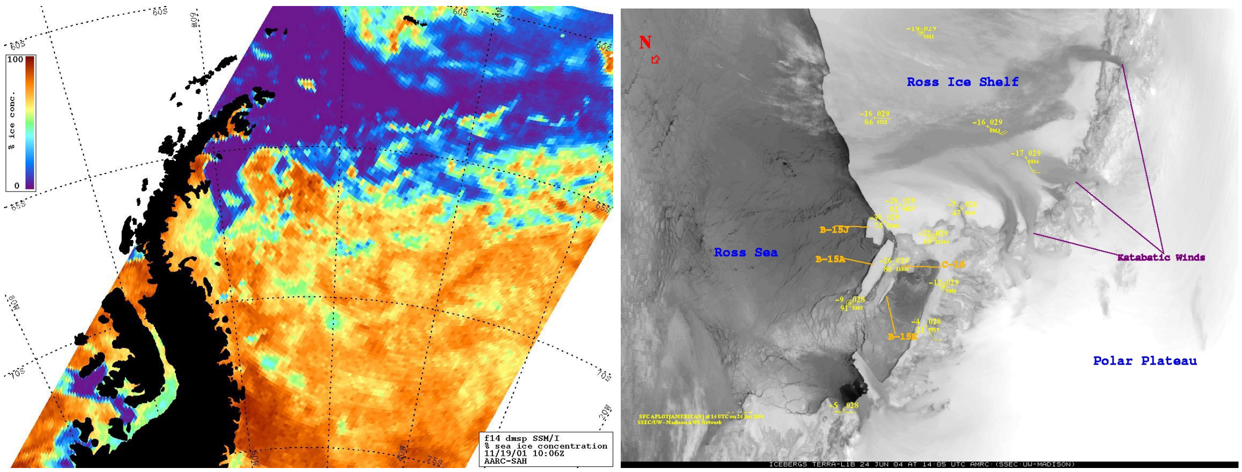


Figure 11. Sample sea-ice depiction products using DMSP SSM/I sensor with oranges and reds denoting high concentrations of sea-ice, and blues and purples showing lower concentrations of sea-ice (left, *courtesy of AARC*) and iceberg monitoring products using Terra MODIS (right, *courtesy of AMRC*).

Spectral Channel Combinations

A seemingly simple, yet powerful application of satellite data are the combinations of the various spectral channels to enhance features in the data that are of keen interest to forecasters. For example, as depicted in Figure 12, the combination of three channels can clearly enhance cloud features, and give indications of the height of the clouds (low, middle, high), based on color, shading and depiction. Some of the depictions are only possible with available sunlight, but other combinations can be done with infrared channels only as the figure denotes. Other multi-channel and “super-channel” combinations are being researched actively as newer sensors such as AIRS offer thousands of channels and require the deluge of data to be converted into a more easily used and understood presentation.

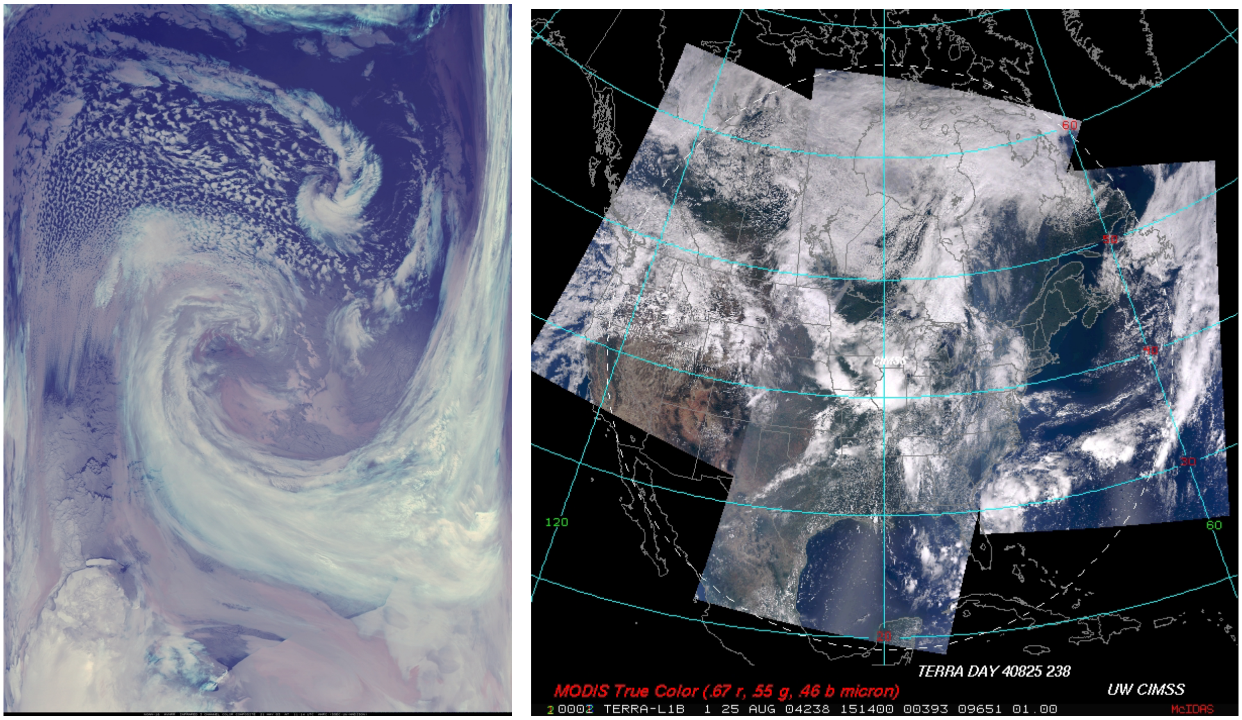


Figure 12 Two examples of three channel combinations from NOAA-16 AVHRR using the shortwave, window and longwave infrared channels (left), and Terra MODIS using the three natural color visible channels (right, *courtesy of K. Strabala and CIMSS*) Both of these combinations enhance features in the imagery.

Potential Satellites to Benefit USAP Operations

In the short run, it is clear that the USAP will continue to need to utilize the traditional polar orbiting satellite platforms (NOAA, DMSP, and SeaStar). Meanwhile, in the coming years, the next generation polar orbiting satellites (Terra, Aqua, NPP, etc.) will need to be integrated into the forecast office. The learning curve to work with these new satellites is not trivial. Lessons and experience with these next generation satellites will prepare the USAP for the use of future operational polar orbiting platforms (NPOESS, MetOp, etc.).

In the mid-term, the USAP may benefit from the ability to acquire and utilize other satellites such as OceanSat or future FY-1 or FY-3 series satellites. In the long run, the polar stationary satellite platform offers the most promise. If the platform becomes available, it gives the Antarctic its first "geostationary" like observing, with routine hourly, half-hourly or even rapid-scan coverage of a large portion of the Antarctic.

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 in the best position possible with the assets available or soon to be available in space.

Data Encryption

The availability of satellite observations over the years has encountered some issues with availability and data encryption. For many years, some satellite systems have been and currently are, and perhaps understandably, encrypted, including DMSP, SeaStar/SeaWiFS and INSAT. DMSP observations have been unencrypted from 60 degrees South to 90 degrees South, in respect of the Antarctic treaty, providing an important source of weather satellite information for the Antarctic, and adjacent waters. With SeaStar/SeaWiFS being a public/private satellite system, NASA has arranged for data to be freely available and unencrypted for registered users who have a science research project use for the data stream, as is the case for the US Antarctic Program. Other satellite systems have in recent years been added to this list, such as the Meteosat satellite series. These data are not all encrypted due to international treaty. Data every six hours is available in real-time without encryption. Other rules on redistribution of Meteosat data also apply, depending on availability. Redistribution restrictions have also in the past been imposed on GMS data as well.

Recently, new partial data encryption policies have been announced on the MetOp and NPOESS future satellite platforms. For the MetOp satellite series, the European sensors (e.g. IASI, GOME, etc.) will be encrypted all of the time. However, the US sensors will not, unless EUMETSAT is asked to do so by the US Government. It also appears that DCS (Service ARGOS) and all Search and Rescue (SAR) capabilities will never be encrypted. For NPOESS, the policy will be similar. With the Integrated Program Office (IPO) planning to offer a required software and key registration for anyone to acquire and use NPOESS data streams, the encryption will be tiered. It is expected that during nominal operation, all NPOESS sensors and data streams will be available freely. However, at the request of the US Government, encryption can be imposed over a geographical region, by sensor, and/or by registered user. Like MetOp, it is expected that DCS (Service ARGOS), and all SAR capabilities will never be encrypted.

In general, there have been concerns over the limited availability of some satellite systems observations. This is a part of a larger discussion that the World Meteorological Organization (WMO) has taken up in the past, and specifically what is widely known at WMO Resolution number 40. Although this resolution has much of the middle and tropical latitudes in mind, it is hoped that the Antarctic Treaty, and the free exchange and availability of data will dominate for the Antarctic and adjacent waters.

Frequency Spectrum Threats

In recent years, the portions of the electromagnetic spectrum that are used or may be used in the future for meteorological remote sensing from satellite platform have been under attack. As it turns out, not all of the likely frequencies that have or may be of important value to meteorological satellite observations are completely protected by international agreement, and are reserved for passive remote sensing. Hence, some of these frequencies have been requested by other industries for commercial and consumer use, such as for car radar systems which are under development (Rochard, 2004). Currently this threat impacts some of the microwave portion of the spectrum (near 24 Ghz), as well as some of the frequencies used for satellite data transmission. This threat will likely grow. If current and future research efforts reveal important applications in these threatened regions of the spectrum, they may suffer from debilitating interference from other uses. Hence, it is important for the USAP, and more formally, the NSF to encourage that these unprotected bands become protected by international agreement and reserved for remote sensing applications and Earth discovery.

Summary and Considerations

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

- Review of the status of current and future meteorological and related satellites.
- The USAP forecast operations currently benefit greatly from meteorological satellites.
- Meteorological satellite observations and products over the Antarctic have started to have the chance to be put to increased use in numerical modeling efforts. This effort should be continued and increased especially for those observations and products that positively impact the numerical forecast output. Derived products from satellite observations not only are input for numerical modeling efforts but also must be available for direct use by weather forecasters.
- The USAP is starting to become active in acquiring new data streams of satellite data (i.e. X-band polar orbiting platforms). This effort is applauded and must continue with backup and additional systems for reliability and increased acquisition.
- The USAP must strongly consider the polar stationary satellite, as a long-term solution to its meteorological satellite and possibly communications needs. If such a platform becomes available, it offers the chance to nearly eliminate the data gap. It also offers a geostationary like set of routine and more frequently available observations to forecasters.
- The USAP and NSF have a duty to inform satellite-operating agencies such as NOAA, the Department of Defense, and NASA of its support requirements for operations and research. The USAP has, from an operational point of view, articulated its meteorological satellite needs to satellite operator agency NOAA in 2002 (Cayette, 2002). It is important for the USAP to continue to communicate its needs, both operational and research, to NOAA and to the other important satellite agencies named above as well as partnership agencies such as the IPO.

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 needs on station
- High data volume connectivity for return to the mid-latitudes for supporting use.
- Satellite coverage and data gap issues

- Training and education along with operational integration
- Funding to solve these problems and meet goals as well as maintain an active research, development and operational program.
- Data encryption issues
- Threats to the frequency spectrum

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

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On-line Resources

This document was nearly completely created using information available via Internet from official and unofficial sources. 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, a limited set of explicit references (see above) have been made with the text. However, a list of web sites is given below that were the major sources for much of the information contained within this report. It is important to note that this report, especially the future launch dates and status of operating satellites, is subject to change, and that within three to six months the contents of this report, in this respect, are likely to be somewhat outdated.

United States Antarctic Program Meteorological/Satellite Data sites:
- http://amrc.ssec.wisc.edu/
- http://arcane.ucsd.edu/
- http://nsidc.org/usadcc/

Japanese Meteorological Agency (JMA):
- http://www.kishou.go.jp/english/index.html
- http://mscweb.kishou.go.jp/general/future_plan/index.htm
- http://mscweb.kishou.go.jp

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
- http://www.cma.gov.cn/ywwz/constitute/nsmc.php
- http://nsmc.cma.gov.cn/fy2e.html

Australian Bureau of Meteorology (ABOM):
- http://www.bom.gov.au/
- http://www.bom.gov.au/sat/MTSAT/MTSAT.shtml
- http://www.bom.gov.au/sat/Othersat/othersats.shtml

United States/NOAA/NASA:
- http://www.noaa.gov
- http://www.nasa.gov
- http://noaasis.noaa.gov/NOAASIS/ml/launch.html
- http://www.oso.noaa.gov/operation/index.htm
- http://www.oso.noaa.gov/goesstatus/
- http://www.oso.noaa.gov/poesstatus/
- 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://nssdc.gsfc.nasa.gov/nmc/sc-query.html

India Meteorological Department (IMD)/ Indian Space Research Organization (IRSO):
http://www.isro.org/
http://www.imd.ernet.in/
http://www.isro.org/programmes.htm:
http://www.isro.org/insat3e/pg1.html

EUMETSAT/ESA:
http://www.eumetsat.de/
http://www.esa.int/
http://www.esa.int/export/esaME/ESAPY1094UC_index_0.html
http://www.esa.int/export/esaME/ESAMG1094UC_index_0.htm

France/CNES:
http://smsc.cnes.fr/PARASOL/index.htm

Canadian Space Agency:
http://www.space.gc.ca/asc/eng/media/press_room/news_releases/2004/040206.asp

Taiwan:
http://www.nspo.gov.tw/e50/home/index.html
http://www.nspo.gov.tw/e50/home/index.html

Miscellaneous:
http://fas.org/spp/guide/china/earth/index.html
http://fas.org/spp/index.html
http://www.teamencounter.com/
http://www.itc.nl/research/products/sensordb/Launch_Schedule.aspx
http://www.satsignal.net
http://celestrak.com/
http://www.satelliteonthenet.co.uk/launch.html
http://pages.ivillage.com/spacehorizons/id23.html
http://www.spaceflightnow.com/tracking/index.html
http://www.boeing.com/defense-space/space/bss/factsheets/601/goes_nopq/goes_nopq.html
http://www.astronautix.com/craft/insat3.htm
http://www.spaceandtech.com/spacedata/logs/2002/2002-043a_metsat-1_sumpub.shtml
http://www.tbs-satellite.com/tse/online/mis_meteo_geo.html
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http://www.allmetsat.com/en/weather_satellites.html
http://www.sinodefence.com/space/spacecraft/fy1.asp
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http://www.designation-systems.net/dusrm/app3/s-1.html