Western Region Technical Attachment
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GOES-9 UPDATE

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Introduction

GOES-9 will be positioned at 135° W by January 22, 1996 to become GOES-WEST. This will signal a new era in satellite meteorology for the Western Region (WR). Previous WR experience with the new series of GOES satellites has been limited to the use of the RAMSDIS GOES-8 fog/stratus product. This Technical Attachment will discuss:

1) The differences between the old series of satellites (GOES-1 through GOES-7) and the new GOES-I/M series. Please note: The satellite is called by a letter until the satellite safely reaches orbit, at which time the letter is changed to a number (i.e., GOES-J became GOES-9).

2) The method of ingest and transfer of GOES-9 data.

3) The data products that will be available from GOES-9.

Differences Between Old GOES and GOES-9

GOES-7, the current GOES-WEST, is a spin stabilized spacecraft that rotates at 100 rpm. The imager and sounder instruments are attached to the body of the spacecraft and therefore rotate as well. The instruments scan one line on the earth as the earth passes and then ratchets down one step to scan the next line as the instruments face the earth again. The satellite scans the earth from west to east and with a rotation rate of 100 rpm, GOES-7 can produce 100 scan lines per minute. It takes approximately 20 minutes for GOES-7 to scan the earth (i.e., full disk). As a result of the spinning satellite, the earth is viewed only 5 percent of the time by GOES-7. This does not allow for good signal-to-noise ratios of the instruments or high spatial resolution. Another disadvantage is that the solar panels only point at the sun about 10 percent of the time which limits available power to the instruments. An advantage of the spinning satellite is that the instruments stay in good thermal equilibrium. This reduces thermal gradients which can warp the spacecraft's structure. In the normal mode of operation, imagery is provided every 30 minutes. In severe weather situations imagery can be made available for the CONUS only, every 5 minutes.

GOES-9, a three axis stabilized spacecraft, remains stationary in space which allows the instruments to be continuously pointed at the earth. The scanning system moves back and forth (i.e., east to west and then west to east) as it moves north to south. While the spacecraft is stationary, it is not absolutely still. Earth location and registration accuracy are effected by orbital motions, instrument motion, and thermal distortion. A complicated set of navigation (earth location) and registration (image-to-image location of a landmark) correction schemes are necessary to compensate for these effects. The navigation schemes briefly are: 1) "Star sensing" to keep the instruments pointed at the earth, 2) semi-automatic landmark measurements, and 3) range to the satellite that is determined by the time elapsed between uplink and downlink signals to the satellite. The registration schemes briefly are: 1) image motion compensation (IMC), and 2) mirror motion compensation (MMC). The IMC removes spacecraft orbit and attitude motion from each image. The MMC automatically corrects for the predictable effects of the instrument mirror motions. The ability of the IMC and MMC to correct navigation and registration problems varies with time of day and season. During normal operations (dual-chord) the satellite senses the earth edges in both the Northern and Southern Hemispheres to more precisely correct navigation. These correction schemes can be affected when the sun or moon are near the edge of the earth, as viewed by the satellite. During these times, single chord operations are required. Single chord operations mean that the earth position is determined from only sensing the earth's edge in either the Northern or Southern Hemisphere. It is during single chord operations that the image navigation procedures are most likely to be negatively affected. Efforts are underway at NESDIS to minimize the effect of single chord operations.

On GOES-7 the imager and sounder share the same optics. As a result, imaging and sounding operations cannot take place simultaneously. Sounder operations being frequently interrupted and the poor signal-to-noise of the sounding instrument has resulted in the sounder being primarily used in an experimental mode only. The GOES-9 imager and sounder have separate optics and can therefore operate simultaneously. This allows for more efficient duty cycles for both the imager and the sounder, which improves the instrument signal-to-noise ratios.

The GOES-7 imager scans only two spectral bands, visible (0.55-0.75 μm) and window IR (10.4-12.1μm). Forecasters also use data from the sounder, (normally the 6.7 μm water vapor band). The GOES-9 imager has five spectral bands: 1) 0.52-0.72 μm (Visible), 2) 3.78-4.03 μm (shortwave IR window), 3) 6.47-7.02 μm (Water Vapor), 4) 10.2-11.2 μm (IR), 5) 11.5-12.5 μm (split window IR with sensitivity to low-level water vapor). Table 1 shows the comparison of GOES-7 and GOES-9 imager characteristics. IGFOV is the resolution of an individual element. GOES-9 senses a square field of view and therefore a 4 x 4 km IGFOV is frequently called 4 km resolution. The GOES-9 images in these bands are sharper than GOES-7 due to improved quantization in the visible band and lower signal-to-noise and increased resolution in the IR and water vapor bands. The lower noise in the visible band should allow: 1) better cloud edge and cloud top feature detection, 2) better low-light images (near sunrise and sunset), 3) better detection of haze and pollution, 4) improved cloud motion measurements, and 5) allow for use of data beyond the satellite's 60 degree zenith angle. In all IR bands, the improved spatial resolution will allow for better identification of mesoscale features. The higher noise level at colder temperatures in the shortwave IR band will show up as a speckling pattern in cold cloud

tops. Lower noise levels in the water vapor band allow for better identification of upper-level features such as shortwaves.

Table 2 lists some examples of what each of the bands on GOES-9 can be used to detect.

Table 1. GOES-7 and GOES-9 imager characteristics. IGFOV is Instantaneous Geometric Field of View at nadir.

Wavelength (μm)	Common Name	IGFOV(km) E/W x N/S	Noise	
GOES-7				
0.55-0.95	visible	0.75 x 0.86	6-bit data $\pm$ 2 counts 3 σ	
6.40-7.08	water vapor	13.8 x 13.8		1.0 K @ 230 K
10.4-12.1	IR	6.9 x 6.9	0.10 K @ 300 K,	0.20 K @ 230 K
GOES-9				
0.52-0.72	visible	1.0 x 1.0	10-bit data $\pm$ 8 counts 3 σ	
3.78-4.03	shortwave IR	4.0 x 4.0	0.15 K @ 300 K,	3.50 K @ 230 K
6.47-7.02	water vapor	8.0 x 8.0		0.18 K @ 230 K
10.2-11.2	IR	4.0 x 4.0	0.13 K @ 300 K,	0.40 K @ 230 K
11.5-12.5	split window IR	4.0 x 4.0	0.24 K @ 300 K,	0.40 K @ 230 K

Note: IGFOV is commonly called image resolution, i.e., 1 x 1 visible is called 1 km resolution visible.
Note: The shortwave IR is most commonly call the 3.9 channel.
Note: The water vapor from GOES-7 is from the sounder

Table 2. Example uses for each imager band on GOES-9.

Wavelength (μm)	Common Name	Phenomena detected
0.52-0.72	visible	clouds, snow cover, and haze/pollution
3.78-4.03	shortwave IR	fog/stratus, ice vs. water clouds during daylight, clouds over snow
6.47-7.02	water vapor	synoptic patterns, mesoscale features, upper-level winds
10.2-11.2	IR	cloud top temperature, surface temperature (land and water)
11.5-12.5	split window IR	low-level moisture (in combination with longwave IR)

The GOES-7 sounder has 12 IR bands, compared to 18 IR bands on the GOES-9 sounder. The

GOES-9 sounder provides brightness temperatures with a 1.0 K absolute accuracy. The sounder on GOES-9 will provide full-time operational products. This will allow for better estimates of temperature and moisture profiles, the supplementation of ASOS upper-level cloud information, and monitoring ozone.

Note: A new COMET module (SATMET1) will be distributed to PDW sites early next year providing additional background on GOES-8/9.

Method of Ingest and Transfer of GOES-9 Data

GOES-9 data for the WR RAMSDIS systems will be ingested by a direct receive system using Global Imaging HIPS software and an antenna at the Naval Research Laboratory-Monterey. The Monterey ingest machine is an HP 715 that is dedicated to GOES-9 ingest. Special software developed by the Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison will transmit the satellite data from the HP ingest machine in Monterey to the WR file server (HP 755) at NWSFO-SLC via a 512Kb line dedicated communication line. Local RAMSDIS machines at Western Region field sites will access the data from the WR file server using a timed scheduler. The scheduler executes commands that check the WR file server for new image products every 3 minutes. Once a new product is detected on the server, a capture command is scheduled to execute that will send the data to the local RAMSDIS. This delay is necessary to avoid capturing incomplete images on the local RAMSDIS machine. The image products should be available for viewing on the local RAMSDIS within 15 minutes of image time (the image time is the time that the satellite starts scanning for a particular image). In most scanning scenarios, the entire Western Region's area of interest will be scanned by 5 minutes after image time.

There are a number of interesting sounder capabilities that SSD will be making available to the field this spring. For example, the sounder is capable of producing hourly moisture fields over the Pacific Ocean, similar to the SSMI data. GOES-9 sounder data (imagery and data files) will initially be sent to the WR file server via FTP from SSEC. This data will eventually be received from NESDIS when the GOES-9 sounder product routines become operational. The sounder data will be less reliable and timely than the imager data since SSEC is not an operational unit.

Data Products Available From GOES-9

GOES-9 will provide an improvement in quality of the current RAMSDIS product suite available from GOES-7. Visible and IR will still be available, but with better signal-to-noise and spatial resolution. In addition, the shortwave IR window (3.9 μm) and water vapor band (6.7 μm) will be routinely available at much better resolution than was available with GOES-7. All GOES-9 data will be ingested in Monterey at the normal 15 minute image interval and any rapid scan data will also be ingested. Sending 15 minute interval data to the WR file server from the ingest machine will be tested using GOES-8 data during late December 1995. This will determine how

much of the 15 minute interval data can be transmitted to the WR file server and therefore be made available to field sites. The possibility of sending special rapid scan data will also be tested.

The products that will be routinely available on the WR file server once GOES-9 data is available are shown in Table 3. A macro exists (SKEDSECT) that will allow each RAMSDIS site to select a sector of any data type and choose the display resolution. This selectable sector will load into the RAMSDIS applications loop. This sector can be changed at the site's discretion. In addition, GOES-9 sounder derived product imagery (DPI) and profiles will be made available in as timely a manner as possible. The DPI imagery may include: 1) total precipitable water, 2) lifted index, 3) lower-level (1000-700mb) relative humidity, 4) upper-level (700-300 mb) relative humidity, and 5) surface skin temperature. The profiles of temperature and moisture may be displayed as SKEWTs on RAMSDIS. Sounder data will generally have a time resolution of 1 hour and a spatial resolution of 10 km at the satellite subpoint.

Table 3. GOES-9 data products that will be available on the WR file server.

Data type	IGFOV E/WxN/S(km)	Displayed Resolution E/WxN/S (km)	Frequency
Full res VIS	1.0 x 1.0	1.0 x 1.0	30 min (possibly 15 min)
Reduced res VIS	1.0 x 1.0	4.0 x 4.0	30 min
Full res IR	4.0 x 4.0	4.0 x 4.0	30 min (possibly 15 min)
Full res shortwave IR	4.0 x 4.0	4.0 x 4.0	30 min
Full res water vapor IR	8.0 x 8.0	4.0 x 4.0	30 min
Fog/stratus product	4.0 x 4.0	4.0 x 4.0	30 min (possibly 15 min)
Hemispheric scale IR	4.0 x 4.0	24 x 24	60 min
Hemispheric scale WV	8.0 x 8.0	24 x 24	60 min

Summary

The introduction of GOES-9 imagery to field sites in Western Region should provide improvements such as: 1) more details seen in all imagery, 2) improved composite (product) imagery, 3) better synchronization with other observations (such as NEXRAD), 4) improved detection of upper-level flow features in the water vapor IR band, 5) better detection on fog at night, and 6) more timely imagery that can be used for more effective nowcasting.

References

Menzel, W.P., and J.F.W. Purdom, 1994: Introducing GOES-I: The First of a New Generation of Geostationary Operational Environmental Satellites. *Bull. Amer. Meteor. Soc.*, **75**, 757-781.

Purdom, J.F.W., and W.P. Menzel, 1995: Near Term Opportunities and Past Impacts of Space-Based Data in Operational Weather Forecasting, *14th Conf. on Weather Analysis and Forecasting,* Dallas, TX, Jan. 15-20, AMS, Boston, 295-306.