N78-14548

PROCESSING OF SATELLITE IMAGERY AT THE NATIONAL ENVIRONMENTAL SATELLITE SERVICE

M. Crowe

U.S. Department of Commerce, NOAA
National Environmental Satellite Service
Washington, D.C. 20233

ABSTRACT

The National Environmental Satellite Service (NESS) image product processing system is a subset of the polar-orbiter satellite and the geostationary satellite systems. These systems enable the day and night monitoring of the environment from markedly different perspectives, thereby fulfilling the needs of an international spectrum of public and private users in the environmental and earth sciences.

This paper is divided into four sections:

1. Overview of the Satellite Data Processing Systems.
2. Image Processing of Polar-Orbiter Satellite Data.
3. Image Processing of Geostationary Satellite Data.
4. Quality Assurance and Product Monitoring.

1. OVERVIEW OF THE SATELLITE DATA PROCESSING SYSTEMS

There are many physical components that are functionally common to both the polar-orbiting and geostationary satellite systems. The earth environmental sensors include the Scanning Radiometer (SR) and the Very High Resolution Radiometer (VHRR) aboard the polar orbiters and the Visible Infrared Spin Scan Radiometer (VISSR) on the geostationary series. Each of these instruments is sensitive to energy in the visible and infrared portions of the electromagnetic spectrum.

Some nonsensor subsystems deal with spacecraft and ground-based command, communications, and power to allow the following functions to be performed:

(1) spacecraft command and command verification;
(2) receiving and processing of telemetry (system performance measurements);
(3) tracking of spacecraft for position/orbit determination and subsequent prediction;
(4) data flow throughout system;
(5) spacecraft attitude determination and prediction; and
(6) data calibration, processing, and display.

All of the above functions and others must be executed properly if image data processing and analysis are to be worthwhile. For example, although a sensor is calibrated and tested extensively prior to launch, the inflight monitoring of its performance is necessary to assure measurement accuracy. Also, knowledge of the precise position and attitude of a spacecraft is vital to the accurate earth location of the data and utility of most image products.

The performance of the above functions is handled by the four major operational elements of the NESS satellite system:

(1) The Satellite Operations Control Center (SOCC).

(2) Two Command and Data Acquisition (CDA) Stations in Wallops Island, Virginia, and Gilmore Creek, Alaska.

Preceding page blank

(3) Ground-based and satellite communications networks.

(4) A quasi-central processing, analysis, and distribution center (the Office of Operations in Suitland, Maryland, and the Central Data Distribution Facility (CDDF) in Camp Springs, Maryland).

The SOCC is responsible for the continuous monitoring, evaluation, and direction of the performance of the spacecraft and data acquisition systems. The CDA stations handle data acquisition, processing, and dissemination using a variety of communications subsystems. The central processing and distribution facilities use a number of computers with manual intervention to ingest, reformat, digitize, earth-locate, display, and quality control the sensor data and subsequent derived products.

2. IMAGE PROCESSING OF POLAR-ORBITER SATELLITE DATA

2.1. SR DATA

Reflected and radiated energy from the Earth is continuously detected in detected in the appropriate wavelengths by the scanning radiometer aboard the polar-orbiting satellites. The SR mirror scans across the spacecraft track from horizon to horizon. The spatial resolution of the ground field decreases away from the subsatellite point, where the visible and infrared channels can resolve 3.2-km and 6.4-km "spots," respectively. The sensor information is recorded on magnetic tape aboard the spacecraft and is played back to the CDA stations when the satellite is within transmission range. The data enter the NESS Suitland facility through hardware/software components, dubbed the Digital Data Handling System, and are demodulated, separated, digitized, and transferred to the NESS large-scale computer (IBM S360/195) for further processing.

Image product processing of SR data includes the creation of:

- polar-stereographic mapped mosaics
- Mercator-mapped mosaics
- time-composites of mapped data
- pass-by-pass gridded images

2.2. MAPPED MOSAICS

The mapping of image data can be broken down as follows.

2.2.1. CALIBRATION

The infrared data are corrected using prelaunch instrument calibration results and continual inflight blackbody versus outer-space temperature comparisons.

Also, a brightness correction is applied to the visible data using a prelaunch-determined relationship between the SR instrument response and solar equivalent brightness.

2.2.2. ENHANCEMENT

The infrared data are also corrected for the attenuation of the signal passing through the Earth's atmosphere. Water vapor is considered the major attenuating constituent.

A correction is made to the visible data for differences in solar illumination of the Earth scene due to varying sun angle.

2.2.3. EARTH LOCATION

The mapping process continues with the earth location of a subset of data points or "benchmarks," using such information as predicted satellite orbital position, attitude, time, and a knowledge of sensor geometry. The benchmark latitude and longitude inputs are transformed into coordinates in the desired map projection array. Since the mapping is done on a pass-by-pass basis, the limits of this array must also be computed. The mapping resolution is substantially poorer than that of the raw data, creating a surplus of samples for each mapped location.

2.2.4. MAPPING PROCEDURE

Using the calibrated, enhanced data and the benchmark data array and array limits as input, the mapped position coordinates for each sample are computed by a linear interpolation. Redundant plotting of samples into the mapped sector of desired resolution is done until the input data are depleted. The mapped sector is then transferred to disk storage, awaiting further product processing.

Three mapped data bases exist for both the polar-stereographic and Mercator projections:

- visible
- nighttime infrared
- daytime infrared

Each of the polar-stereographic mapped arrays is aligned with the National Meteorological Center's (NMC) Numerical Weather Prediction grid for ease in meteorological application of the satellite imagery. The mapped resolution varies from approximately 15 kilometers at the equator to 30 km at the poles.

The Mercator-mapped arrays are aligned parallel to the equator, covering a latitude belt from 40°N to 40°S along the full Earth longitudinal span. The resolution is approximately 10 km at the equator with an improvement poleward.

2.3. PASS-BY-PASS GRIDDING

Due to the computer resource cost and unsuitability for some user applications of mapped data, NESS also produces pass-by-pass gridded imagery. While mapping entails the fitting of the data to conform to a mapped projection, gridding involves the placement of grids into the data stream in the proper geographical locations (or more precisely, at the proper time). The grids consist of latitude/longitude lines and geographical/political boundaries. The earth location (or data stream positioning) of the grids is accomplished once a day for the following 14 orbits of the spacecraft using predicted satellite orbit and attitude, time, and geometry. A grid feature file consisting of geographical/political latitudes and longitudes is used as input to this grid table production.

A table of grid positions, within the data stream, for each orbit of the day is produced.

The melding of grids and data is performed during the creation of each gridded, orbital display product.

2.4. MAPPED TIME COMPOSITES

NESS produces limited area, multiday brightness, and temperature composites of polar-mapped data for specific user application. Areal coverage of ice and snow can be deduced from mapped data by saving only the minimum brightness or maximum temperature value for each mapped point over a multiday--in this case, 10-day--period. This process effectively removes the transient cloud cover, exposing the surface background features for snow/ice extent analyses. The composites are produced daily over the north and south polar regions for the previous 10-day period.

2.5. MAPPED DISPLAYS

The NESS produces a variety of displays of the mapped data bases for user application. These range from photo reproductions of full-hemisphere mosaics to facsimile displays of specific earth sectors. The displays are produced in various map scales, sizes, and areal coverage in response to user needs.

This imaging process begins in the IBM S360/195 with software which processes the data for the Digital Muirhead Display (DMD) devices that produce 25-cm by 25-cm negatives. Photo processing and reproduction are done in the Visual Products Support Branch.

The facsimile display media include the standard weather facsimile networks (FOFAX, NAFAX) using such devices as Alden Electrolytic paper recorders and weather facsimile images rebroadcasted via geostationary satellites (WEFAX) and recorded by users on either photofacsimile or other facsimile recorders.

2.6. VHRR DATA

Both the visible and infrared channels of the VHRR resolve an 0.8-km spot at the subsatellite point. Because of the higher data resolution, only about eight minutes of VHRR data per orbit can be recorded on the satellite. The data can then be transmitted to either of the CDA stations or a readout station located in San Francisco, California. The VHRR system also includes a direct readout capability, the High Resolution Picture Transmission (HRPT) subsystem. Users with proper ground equipment can receive the data as the spacecraft passes within transmission range.

The processing of VHRR data at the NESS (by the Environmental Products Group) consists of a large amount of manual intervention. Hardcopy photographs are received from the ingest facility and are analyzed to generate a number of products with generally hydrological application. These include a Gulf Stream Analysis, Great Lakes Ice Chart, Great Lakes Surface Temperature Chart (in the summertime), Alaskan and Labrador Ice Analyses, and the U.S. Snow Basin Mapping. These products are disseminated by mail, facsimile, teletype, and telecopier.

3. IMAGE PROCESSING OF GEOSTATIONARY SATELLITE DATA

The Geostationary Operational Environmental Satellites (GOES) possess equatorial, earth-synchronous orbits, which allow them effectively to hover over the same earth location continuously. The respective scenes viewed by the VISSR, then, aboard the Eastern Satellite with a subsatellite longitude of 75°W and the Western Satellite, located above 135°W, change very little from picture to picture. The VISSR mirror sweeps from earth horizon to horizon viewing an 8-km swath during each sweep. The mirror is stepped down so that adjacent swaths are viewed during successive sweeps.

The visible and infrared data are transmitted to the Wallops CDA station and are demodulated, synchronized, preprocessed, and retransmitted to Suitland. Much of the preprocessing takes place in the Synchronizer/Data Buffer (S/DB) computer. The visible data, with a raw 1-km resolution, are adjusted for sensor bias and can be reformatted into resolutions of 1, 2, or 8 km. The infrared data may be output in either 8-km or 8x4-km resolutions. These data are sent to Suitland either by retransmission via the Eastern Satellite or landline communications.

The S/DB computer hosts another important event in the GOES imaging system. Earth-located gridding information is produced at Suitland in essentially the same fashion as polar-orbiting satellite grid positions are predicted. In this case, the picture coordinate locations of the political/geographical boundaries and latitude/longitude lines are produced for each picture, instead of on an orbital basis. Inputs to the gridding algorithm include predicted satellite position (orbit), attitude, time, and sensor geometry. The gridding data are transmitted to Wallops via a computer-to-computer link and telephone line named the Grid Transfer System. The S/DB receives and properly inserts the grids into the real-time VISSR data stream for each GOES frame.

The VISSR Ingest Computers (VIC) at Suitland create a data tape that interfaces with the photofacsimile display devices. The data, then, may be saved for later processing and/or displayed in near real time. The NESS Suitland facilities handle only a portion of the display and distribution of GOES imagery. The retransmitted signal from the spacecraft is also relayed via line-of-sight microwave communications to the CDDF in Camp Springs. From there, pertinent data may be routed to any of the five Satellite Field Service Stations (SFSS) located in Washington, D.C., Miami, Kansas City, San Francisco, and Honolulu. Each of the SFSS's serves as a focal point for analysis and distribution of satellite imagery to regional environmental centers.

The VISSR data are available to users in full-disk displays in resolutions of 4-km visible and 4x8 kilometers or 8-km infrared. Sectors of visible data, covering a subset of the full-disk area, in 1- and 2-km resolution can also be formatted at ingest time.

3.1. MOVIE LOOPS

Animated sequences of successive VISSR picture frames called "movie loops" are created daily at NESS using visible and infrared data of different resolutions over varying geographical locations. The process, using an Oxberry 16-mm recorder (a camera system which is designed to produce motion pictures from still-scene sequences), is controlled by a minicomputer.

3.2. ADDITIONAL GRIDDING

The "automatic" gridding system described above is used to provide grids to all GOES images except for 8-km infrared and movie loops. These products use computer-produced overlay grids, hand-fitted over images, which are then photographed. The overlay grids are created using earth-location software, predicted satellite orbit and attitude, time and a master feature file, in a manner similar to the polar-orbiter satellite grid generation process.

In this case, the IBM S360/195 has been used to create data tapes that produce the clear film grid overlays, using the DMD's and photographic processing.

3.3. MAPPING

Some operational mapping of GOES images is performed, but it is done on a limited basis. At this time, two Eastern Satellite pictures are mapped daily--one visible and one infrared, both in Mercator projections. The mapping process is essentially the same as that for the polar-orbiting satellites, involving calibration, earth location of benchmark arrays, interpolation through these arrays, and storage of the mapped information in an area on the S360/195 disk.

Mapped imagery is output in facsimile form for transmission via standard weather facsimile circuits.

3.4. MANUALLY DERIVED ANALYSES

The Synoptic Analysis Section uses multiformatted VISSR, SR, and VHRR imagery to prepare a number of daily, useful meteorological analyses for aid to the analysis and forecast missions of the NWS. Among these are (1) nephanalyses delineating cloud cover and type, (2) windflow and moisture analyses as input to NMC numerical analysis and prediction models, and (3) tropical storm warnings and classifications.

4. QUALITY ASSURANCE AND PRODUCT MONITORING

The quality control function is a necessary part of any system that expects to deliver products in an accurate, timely, and consistent fashion. The NESS Operational Products Monitoring Section (OPMS) performs the monitoring and evaluation of the ingest, processing, and dissemination of data and derived products from the NESS operational satellite systems.

The monitoring by OPMS personnel includes around-the-clock identification and evaluation of real and potential problem areas in the entire NESS product processing system. Such occurrences as the failure of an operational computer program to successfully complete or a breakdown in the facsimile transmission of imagery must be diagnosed. A course of action is then taken which may involve a number of NESS processing components. Many problems are handled immediately while others may require extensive post facto analysis.

Review and discussion of problem areas with pertinent personnel is aided by a weekly briefing conducted by OPMS.

The first year of this quality assurance effort marked an improvement from 75 to 90 percent in the successful output of products from the NESS operational imagery system, despite a large-scale increase in both the number of products and the complexity of the overall facility.

5. CONCLUDING REMARKS

For the sake of brevity, this paper has avoided detailed description of specific image display products. The NESS operational facsimile transmission schedule alone consists of approximately 30 mapped products covering a range of geographical locations, map scales, and data types. To help inform users or potential users of satellite imagery, the National Oceanic and Atmospheric Administration (NOAA) has published a "Catalog of Operational Satellite Products," edited by Hoppe and Ruiz (1974) and will soon publish an updated version, "NOAA Catalog of Products, Chapter III" (Dismachek, 1977). Each of these publications deals with satellite image products and other satellite-derived products, such as alphanumeric messages and digital magnetic tapes, in greater detail than does this paper.

REFERENCES

Johnson, Jimmie D., Frances C. Parmenter, and Ralph Anderson, "Environmental Satellites: Systems, Data Interpretation, and Applications," U.S. Department of Commerce, National Environmental Satellite Service, Wash., D.C., Oct. 1976, 66 pp.

Bristor, C.L., Ed., "Central Processing and Analysis of Geostationary Satellite Data," NOAA Technical Memorandum NESS 64, U.S. Department of Commerce, NESS, Wash., D.C., March 1975.

Fortuna, Joseph J. and Larry N. Hambrick, "The Operation of the NOAA Polar Satellite System," NOAA Technical Memorandum NESS 60, U.S. Department of Commerce, NESS, Wash., D.C., Nov. 1974.

Hoppe, Eugene and Abraham L. Ruiz, Eds., "Catalog of Operational Satellite Products," NOAA Technical Memorandum NESS 53, U.S. Department of Commerce, NESS, Wash., D.C., March 1974.

Dismachek, Dennis C., Ed., "NOAA Catalog of Products, Chapter III" (In preparation as NESS Technical Memorandum).