# RAMSDIS Contributions to NOAA Satellite Data Utilization

Debra A. Molenar,* Kevin J. Schrab,+ and James F. W. Purdom#


## ABSTRACT

The Regional and Mesoscale Meteorology (RAMM) Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS) was developed as part of an effort to get high quality digital satellite data to field forecasters prior to the deployment of the satellite component of the National Weather Service (NWS) Modernization Program. RAMSDIS was created by the National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data and Information Service RAMM Team. RAMSDIS has made significant contributions to NOAA's satellite training and technology transfer program. The project has had a major impact on the utilization of digital satellite data, both nationally and internationally, providing the sole source for high-resolution digital satellite data at some NWS Forecast Offices (FOs) since 1993. In addition to its use in the FO, RAMSDIS has also provided data distribution and research capabilities on a common platform to several NOAA laboratories, allowing for more efficient collaboration on digital satellite data applications and analysis tools, and has been used by the World Meteorological Organization in an effort to provide digital satellite data to developing countries in Central America and the Caribbean.

The RAMSDIS project was innovative for many reasons. This article describes the unique approaches that made the project a success and details RAMSDIS utilization within the NWS and NOAA. The next phase of RAMSDIS implementation in the international meteorological community is also described.


## 1. Introduction

On 13 April 1994, the launch of the Geostationary Operational Environmental Satellite *GOES-I* introduced the first in a series of National Oceanic and Atmospheric Administration's (NOAA's) next-generation geostationary weather satellites. Upon attaining geostationary orbit, *GOES-I* was renamed *GOES-8.* The new GOES satellites utilize a new three-axis stabilized spacecraft design, an improved multispectral imager, an advanced sounder, and a new ground data processing and distribution system (Menzel and Purdom 1994). The GOES-I/M system, one of the major components of NOAA's National Weather Service (NWS) Modernization Program, offers significant advancements in geostationary environmental satellitecapabilities, and with those advancements come education and training needs.

One of the primary responsibilities of the NOAA/National Environmental Satellite, Data and Information Service (NESDIS)/Regional and Mesoscale Meteorology (RAMM) team is research, development, and evaluation of products to utilize all the capabilities of NOAA's advanced weather satellites, and the transfer of those products to the operational community. The team was tasked with *GOES-I* product evaluation and development prior to the launch of the *GOES-I* spacecraft. It soon became clear that there was no existing technology to get the new satellite data to the field users, primarily the NWS forecasters, for such an evaluation.

In response to this challenge, the RAMM Team and staff at the Cooperative Institute for Research in the Atmosphere (CIRA), collocated at Colorado State

*Regional and Mesoscale Meteorology Team, National Environmental Satellite, Data and Information Service, NOAA, Fort Collins, Colorado.
+Western Regional Headquarters, NOAA/National Weather Service, Salt Lake City, Utah.
#Office of Research and Applications, NOAA/National Environmental Satellite, Data and Information Service, Camp Springs, Maryland.
*Corresponding author address:* Dr. Debra A. Molenar, NESDIS/RAMM, CIRA Building, CSU Foothills Campus, W. LaPorte Avenue, Ft. Collins, CO 80523-1375.
E-mail: debm@cira.colostate.edu
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University, developed the RAMM Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS) to provide ingest, display, and analysis of high-resolution digital satellite imagery on a powerful, low-cost PC workstation. NWS Modernization plans called for data dissemination via NOAAPORT, and data processing and display capability via the Advanced Weather Interactive Processing System (AWIPS). At the inception of this project in May 1993, installation of NOAAPORT and of AWIPS workstations was still many years away. The only satellite data available at NWS Forecast Offices (FOs) was from an analog system that could not provide the new digital dataset at full capacity (every 15 min) or full resolution (1 and 4 km). The decreased resolution of the analog dataset made it virtually impossible to see small-scale details in the imagery such as overshooting cloud tops or the subtle grayscale variations between different cloud levels. Therefore, the new satellite data, a costly component of modernization, could not be fully utilized within the NWS. In addition, there were user education and training needs because the new GOES had new instruments with improved resolution. Without early access to the high quality satellite data and without training in the utilization of the new data, there would be a steep learning curve once AWIPS was deployed.

The goals of the RAMSDIS project were to 1) familiarize forecasters with use of the new dataset to lessen the modernization learning curve; 2) solicit feedback on the dataset utility and on dataset products that would be useful in the modernized FO; 3) determine criteria for future satellite sensor systems, which must be developed years in advance of actual spacecraft deployment; and 4) establish a baseline with respect to NWS field knowledge regarding multispectral digital geostationary satellite imagery to determine future training requirements. Realization of those goals would allow for better field training and for improvement in forecasts and in the development of future products and services and would assist with the development of future GOES operational schedules.

The RAMSDIS project was innovative for many reasons. Project goals required development of a data delivery and analysis system that was powerful, easy to use, quickly deployable, reliable, and low cost. No existing system could meet all of these criteria. As a unique solution, several advances were developed for existing technology. High-resolution display software, automated data ingest and display capabilities, and an easy to use menu system were developed at CIRA to supplement the satellite data dissemination and analysis capabilities of the Man computer Interactive Data Access System (McIDAS) created at the University of Wisconsin Space Science and Engineering Center (UW/SSEC). McIDAS is described in detail in Lazzara et al. (1999). These advances created a low-cost, high-powered PC based satellite data ingest, display, and analysis workstation that did not require extensive forecaster training. Data was delivered to FOs automatically via the Internet from a NESDIS server in Camp Springs, Maryland. The creative combination of new and existing technology greatly reduced system design and implementation costs and provided reliability not available with new, untested systems. The first workstations were ready for deployment within 6 months of project start and arrived in FOs in October 1993. Each system was preconfigured at CIRA for site-specific data and network requirements and then shipped to the FO. System installation at each FO consisted of assembling computer components and plugging the system into a network line.

The RAMSDIS project has always been non-operational, aimed at increasing digital satellite data utilization. RAMSDIS has received wide acceptance by field forecasters and research specialists. As of June 1999, workstations were in use at approximately half of the NWS FOs and were also integral to several NOAA research facilities. RAMSDIS workstations in 24 Western Region FOs were supported by the NWS Western Region Headquarters (WRH) in Salt Lake City, Utah, until November 1999. CIRA continues to support over 35 remote sites, including FOs in Alaska and Hawaii, as of November 1999. That number is expected to decrease as improved datasets, applications, and satellite sectors are added to AWIPS capabilities. In addition, the RAMM Team utilizes over 20 in-house RAMSDISs to support routine satellite data ingest and ongoing research. Workstations are also in use at the NESDIS Office of Research and Applications, Atmospheric Research and Applications Division, Cooperative Institute for Meteorological Satellite Studies (CIMSS), Satellite Operations Control Center (SOCC), and Synoptic Analysis Branch (SAB). In addition, NOAA's National Severe Storms Lab (NSSL) and the NWS Operational Support Facility use RAMSDIS for satellite data related research and training. Figure 1 illustrates the NOAA and NWS RAMSDIS sites throughout the United States as of June 1999.

The full impact of RAMSDIS is now being realized as complete AWIPS deployment nears. Without

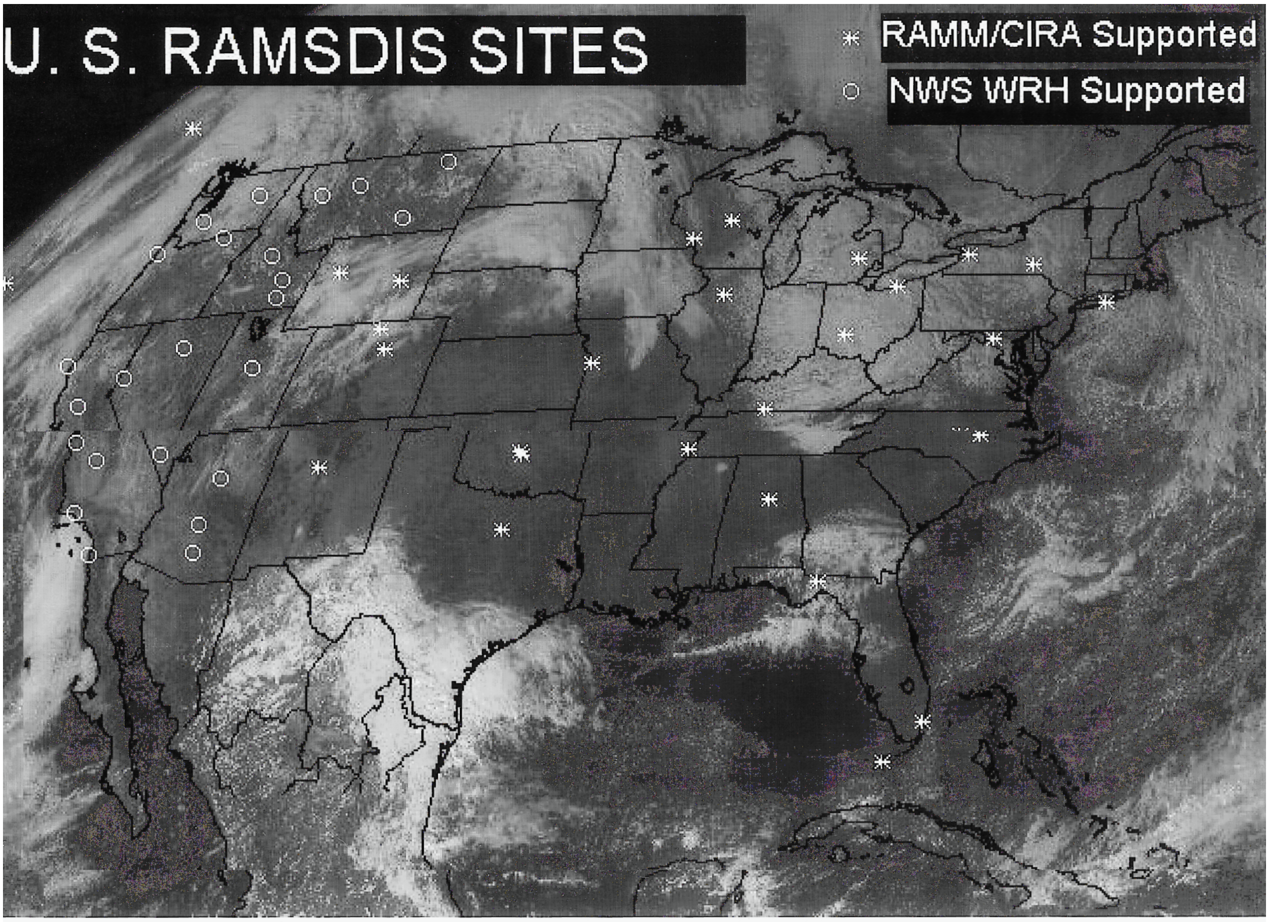


FIG. 1. U.S. RAMSDIS sites.

RAMSDIS, the satellite data interpretation learning curve in NWS FOs would be just beginning instead of turning toward advanced utilization of the dataset as it is today. This paper summarizes RAMSDIS's contributions to NOAA's digital satellite data utilization and training efforts and provides an overview of the far-reaching impacts of RAMSDIS on the operational and research community. As the NWS utilization of RAMSDIS decreases, offshoots of RAMSDIS are being utilized in many additional projects that will also be discussed in this paper.

## 2. System development

There were many constraints and challenges to RAMSDIS development. The system had to be low cost, fast, and easy to use; provide high-resolution display; be able to ingest data; provide an easy mechanism for modifications and for the development of advanced applications; and be ready for field implementation in a short time frame (6 months). All of these factors were crucial to the success of the project and none could be waived. At the beginning of the project, several existing systems and software packages, such as McIDAS-X and OS/2, IDL, GTI, GEMPAK, and the NWS MicroSWIS, were evaluated. After several months of investigation, it became clear that no one existing system would do the job. UNIX workstations provided high-resolution display and performance, but the cost and learning curve were prohibitive. At the time this project was undertaken, no PC based X-Windows satellite display capabilities existed. To develop a system from scratch was not possible within the time frame allowed. Utilizing untested, state-of-the-art technologies ran the risk of unknowns hampering system performance and delaying implementation. Using older, more stable technologies ran the risk of early system obsolescence. In the end, several existing technologies were combined with new capabilities developed by the RAMM Team to meet all the system requirements.

Software stability was a crucial component to the success of the project. For that reason, the McIDAS-OS2 package was chosen for its satellite data ingest and applications development capabilities. The main limitation of McIDAS-OS2 was its display capabilities. Image display was available only in 16 colors, which was not sufficient for analysis of high-resolution digital satellite data and was no improvement to the existing analog system currently available at NWS. The single-monitor display, which required toggling between text and image screens, was also cumbersome and did not fit the "easy to use" criterion necessary for the forecast environment.

Additional display software was developed at CIRA to provide high-resolution (640 × 480 pixels at 256 colors) display capability. Development of the high-resolution display capabilities required creation of many new programs and modification of 40 existing McIDAS programs. In addition, this in-house software had to be maintained and adapted to each new McIDAS upgrade.

In 1993, data assimilation was still a problem. Benjamin Watkins, Chief of the NESDIS Satellite Services Division, agreed to support Internet data access for three initial test sites on the NESDIS VAS Data Utilization Center (VDUC) mainframe in Camp Springs. The new systems were installed at FOs in Seattle, Washington, and Salt Lake City, Utah, in October 1993 and at Cheyenne, Wyoming, in January of 1994. The sites were chosen because of their existing Internet connections, something not available at many FOs in 1993. Satellite imagery, conventional data, and model fields were transmitted to the sites via Internet from the NESDIS VDUC. Due to the patience and valuable input from the staff at these three FOs, many problems were worked out of the initial beta versions of RAMSDIS. The revised system quickly gained acceptance due to its ease of use and ability to aid in forecast decisions, and expansion of the project to 50 field sites was recommended.

Several timely technological advances allowed the project to continue. The VDUC mainframe at NESDIS could not support more than four NWS sites because of port limitations. UW/SSEC provided a demonstration version of its Data Distribution Environment (DDE) software, which allowed for data dissemination from Internet servers instead of mainframes. After a successful DDE demonstration, UW/SSEC quickly developed and released the Abstract Data Distribution Environment, which was more robust and solved most of the data transfer problems inherent with DDE. The final deployment problem was solved by a drop in PC prices. The original 486 PC based workstations were quickly saturated as additional products were added to the system. Lower costs allowed for the purchase of Pentium P5-90s, resolving many performance problems. The RAMM Team also dedicated additional manpower to providing telephone troubleshooting support to all RAMSDIS sites. Once field installation was complete, it became clear that the 56-KB Internet lines at many of the FOs were also a limitation. However, by that time, the satellite data were deemed so important by NWS forecasters that many NWS regions cultivated local funds to install more efficient frame relay networks to support the transfer of this data within the regions.

## 3. System description

*a. Capabilities*

The RAMSDIS workstation currently consists of a 90-MHz or better Pentium processor, 64-MB RAM, two 1.2-GB hard drives, a CD-ROM, a tape backup, an ATI PCI MACH32 graphics adapter with a 17-in. color monitor for image display, and a monochrome monitor for text and command display (see Fig. 2). The system is capable of storing 250 frames of image data in memory at 480 × 640 × 256 color resolution. This is accomplished by overallocating system memory and by utilizing the fast memory and disk-swapping capabilities of OS/2. Because the display software is adapter specific, image information is written directly to adapter registers for image display. This procedure allows animation of imagery at up to 30 frames per second without any screen wiping, something not available for several years in many newer PC systems because of windowing software overhead. Image roam and zoom capabilities were also implemented via software.

*b. Standard products*

RAMSDIS has flexible sector selection capabilities that allow each site to receive a data sector tailored for the needs of the site. The RAMSDIS product set includes standard digital satellite imagery, derived satellite products, and other meteorological data. The satellite data available are shown in Table 1. NWS Western Region sites have a slightly different configuration,with products more suited to analysis and forecasting needs in that region. High-resolution visible (VIS) and infrared (IR) imagery are automatically downloaded from the server every 30 min at CIRA supported sites and every 15 min at NWS WRH supported sites. The 16-km water vapor (6.7 $\mu$m) product is a combination of the *GOES-8* and *GOES-10* large-scale water vapor image so that full U.S. coverage and Pacific region coverage past Hawaii is obtained. This and the 12-km 10.7-$\mu$m IR data are downloaded hourly and remapped to a polar stereographic projection. The 1-km VIS and 4-km 10.7-$\mu$m IR imagery are also remapped into a local radar projection for ease of comparison with a site's Next Generation Weather Radar data. All image loops are updated automatically in a circular queue that rotates the oldest imagery out when new data is received. Each image loop can be accessed via a function key. In addition, topographic imagery corresponding with the 1- and 4-km sectors is provided and functions are set up to allow for comparison of the terrain and satellite imagery to distinguish between, and also determine, the influence of topographic features.


FIG. 2. RAMSDIS image display and command monitors.

RAMSDIS also ingests other meteorological data (see Table 2). Surface data are ingested hourly. The surface data consist of the observations at all SAO sites in the continental United States and portions of Canada and Mexico. Rawindsonde observation (RAOB) data over North America are ingested at 2000 and 1400 UTC daily. Ship and buoy data are ingested hourly at sites with coastal responsibilities. The data can be plotted over satellite data via a function key.

*c. New product evaluation*

One of the most exciting features of the new GOES satellite was the availability of the 3.9-$\mu$m channel. Data from the channel are unlike previous GOES IR channels in that they contain both reflected solar and emitted terrestrial radiation. RAMSDIS provided an ideal platform for the testing of experimental products utilizing this new information. The fog product is generated by subtracting the 3.9-$\mu$m scene temperature from the 10.7-$\mu$m scene temperature and scaling the results to show positive and negative differences. This technique, in use for over a decade with data from polar-orbiting satellites, is based on the principle that the emissivity of water cloud at 3.9 $\mu$m is less than at 10.7 $\mu$m. Figure 3 illustrates a fog product image. The fog product is generated only at night since reflectance complicates the differencing during the day. During the day, a reflectivity product is created by converting the 10.7-$\mu$m scene temperature to an equivalent 3.9-$\mu$m radiance, then subtracting the actual 3.9-$\mu$m radiance from the equivalent radiance. The resulting product is mostly composed of reflected solar radiation. A combined fog–reflectivity product is created during transitionary periods, using the day/night terminator in the visible image as the dividing point. Response from field sites indicate that this product is one of the more useful new products from the GOES satellite data.

Because of the 3.9-$\mu$m detector's unique responses to scene radiance, information from the sensor can also be used to detectfires via subpixel hot regions at 3.9 $\mu$m that are not apparent at 10.7 $\mu$m. RAMSDIS has been used in several experiments to monitor the utility of GOES satellite data in large-scale fire detection and monitoring (Alfaro et al. 1999).

New multichannel products are being developed and evaluated for the detection of volcanic ash, which is significant for aviation hazards because it can cause tremendous damage to aircraft engines that fly through it. Ongoing work revolves around identification of additional ash effects noted in the 3.9-$\mu$m channel, and investigation of three-channel image combinations (3.9, 10.7 and 12.0 $\mu$m) to produce a more robust product for identifying volcanic ash during both day and night. Principal component imagery analysis is being

Table 1. RAMSDIS satellite dataset

| Type | Res. | Loop size (No. frames) |
|---|---|---|
| Visible (0.7 $\mu$m) | 1 km | 16 |
| Visible (0.7 $\mu$m) | 4 km | 16 |
| IR channel 2 (3.9 $\mu$m) | 4 km | 16 |
| IR channel 3 (6.7 $\mu$m) | 8 km | 16 |
| IR channel 4 (10.7 $\mu$m) | 4 km | 16 |
| IR channel 3 (6.7 $\mu$m) | 16 km | 24 |
| IR channel 4 (10.7 $\mu$m) | 12 km | 24 |
| Fog–reflectivity product | 4 km | 16 |
| User selected floating sector | | 16 |

used to help identify the channel combinations most helpful under various conditions. RAMSDIS is being used at the NESDIS Synoptic Analysis Branch to evaluate various versions of the volcanic ash detection algorithms. RAMSDIS fog and reflectivity data along with the standard RAMSDIS imagery, disseminated via the Internet through RAMSDIS Online, are increasingly utilized by researchers and emergency managers to detect fires, volcanic ash, flooding, and other natural hazards. Details on RAMSDIS Online are discussed later in this article.

*d. Data analysis*

RAMSDIS provides numerous satellite data analysis applications developed by the RAMM Team. All applications are accessible via a menu system. These applications include 1) minimum and maximum temperature display for areas beneath the cursor, 2) manual cloud velocity measurement, 3) generation of storm-relative loops via manual or automatic correlation of cloud features, 4) calculation of arrival times for cloud features, 5) linear extrapolation of cloud features as a function of time, 6) shifting and stretching of the color enhancement table to highlight specific features of interest in the imagery, 7) image compositing to aid in detection of convergence zones and areas of potential heavy rain, 8) interactive renavigation of images using landmarks, 9) enhancement of low-light visible images through contrast maximization, 10) omission of bad frames from image loops, and 11) the ability to correct for parallax effects in cloud location due to the satellite view. These applications are designed for easy use so the forecaster does not need to learn lengthy command sequences to get maximum benefit from the products available.

## 4. RAMSDIS use in satellite data utilization training

One of the primary goals of the RAMSDIS project was to assess the baseline of NWS field knowledge regarding multispectral digital geostationary satellite imagery in order to implement new training programs. While this objective is an ongoing goal of the RAMM Team, many accomplishments have been made because of the RAMSDIS project.

Several computer-based tutorials have been developed at CIRA to introduce the user to the new capabilities afforded by the GOES-I/M satellites (Phillips and Purdom 1996). “An Introduction to *GOES-8*” covers basic capabilities of the *GOES-8* satellite and provides comparisons between *GOES-7* and *GOES-8* imagery. “An Introduction to the GOES Imager” reflects the considerable experience that has been acquired by RAMM Team meteorologists with the GOES sensors, their data, and the derived application products over the last four years, and it provides many examples of imagery taken from the extensive CIRA archive. “Use of GOES 3.9 Micron Imagery” details the unique capabilities of the GOES 3.9-$\mu$m imaging channel. “Advanced Uses of the GOES Imager” deals with the more advanced use of the GOES Imager and its derived image products. The tutorials are installed on each RAMSDIS system and can also be accessed via the RAMM Team Web site at http://www.cira.colostate.edu/ramm/rsp/ramtblz3.htm.

Table 2. RAMSDIS meteorological dataset

| Type | Frequency |
|---|---|
| Surface data | Hourly |
| RAOB data | Twice daily |
| Ship/buoy data | Hourly |

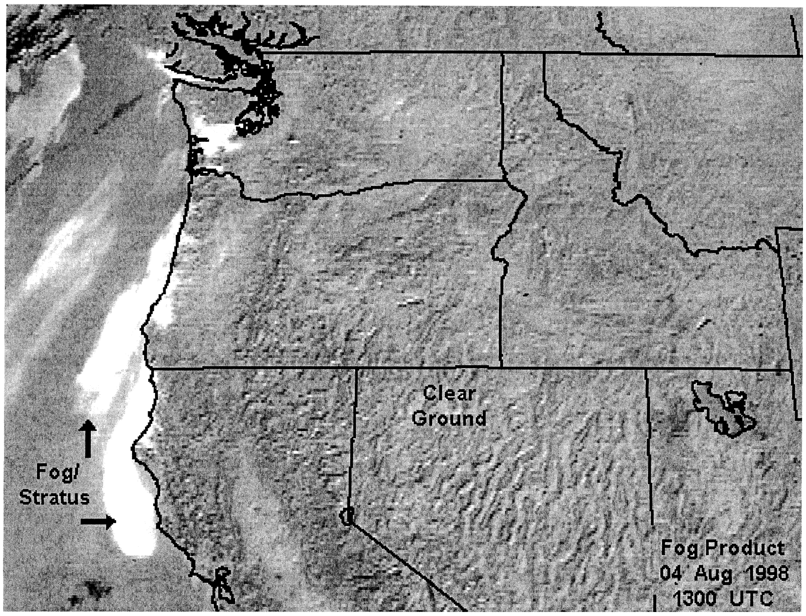


FIG. 3. In this nighttime fog product example, the areas of fog and stratus are clearly seen to be brighter than the land features over Nevada, northeast California, and southwest Oregon.

Each CIRA RAMSDIS site received an initial 2–3-day visit by a RAMM–CIRA meteorologist to cover the basics of satellite data interpretation and system utilization. All RAMSDIS sites have access to an electronic mail group for use in questions, answers, and discussion of features observed in their local satellite data. The RAMM Team also provides routine Web-based discussions of interesting weather events, which can also be viewed in retrospect on the RAMM Team Web site.

RAMSDIS Online (ROL) is a popular offshoot of the field RAMSDIS project. ROL is a Java-based package developed at CIRA for satellite data display on the World Wide Web (Watson and Hillger 1999). It provides animated sequences of real-time satellite imagery from RAMSDIS workstations set up to ingest GOES-East and GOES-West satellite sectors. Also available are generated products including nighttime fog, daytime reflectivity, sounder precipitable water, and sounder lifted index. ROL includes links to basic information for each GOES channel or product. Users also have access to the RAMM Team tutorials. Currently, an average of 400 users per day access ROL. User feedback indicates that ROL is utilized by a diverse national and international audience. ROL is a particularly useful tool for the dissemination of current satellite imagery over special interest sites. During the past year, ROL has expanded from the popular U.S. coverage to other image sectors and features of interest, and tailored ROL sectors are frequently set up to show data over large-scale fires and severe weather events. Figure 4 shows a GOES experimental fire product available from one of the special ROL sectors covering the Florida wildfires during the summer months. ABC News has utilized ROL data on several programs, and CIRA has received praise for ROL utility from as far away as Brazil and Australia.

A means was needed for user testing of experimental products prior to operational implementation. RAMSDIS Online Experimental was developed by the RAMM Team to provide users in the meteorological community with access to new and experimental digital satellite data and products. Most of the products are derived from GOES data, but other satellite products [such as from the Advanced Microwave Sounder Unit (AMSU)] are also being made available. Feedback on the new products available on ROL and ROL Experimental is helping to improve existing products as well as show the potential for new products not normally experienced by weather analysts and forecasters.

ROL also has a great deal of potential for interactive Web-based training capabilities, and VisitView, a modified version of ROL created at UW/SSEC, us used to conduct remote training in the NWS Virtual Institute for Satellite Integration Training program. ROL and VisitView are training tools that can reach a large number of users at minimal cost. ROL can also be viewed from the RAMM Team Web site.

Finally, RAMSDIS workstations have been a component of the SatMet training course at the Cooperative Program for Operational Meteorology, Education, and Training (COMET), providing real-time and case study data for NWS Science and Operations Officer and Forecaster training.

## 5. RAMSDIS use in joint research and field study support

In addition to its use in routine forecasting and training, RAMSDIS has also been utilized to support

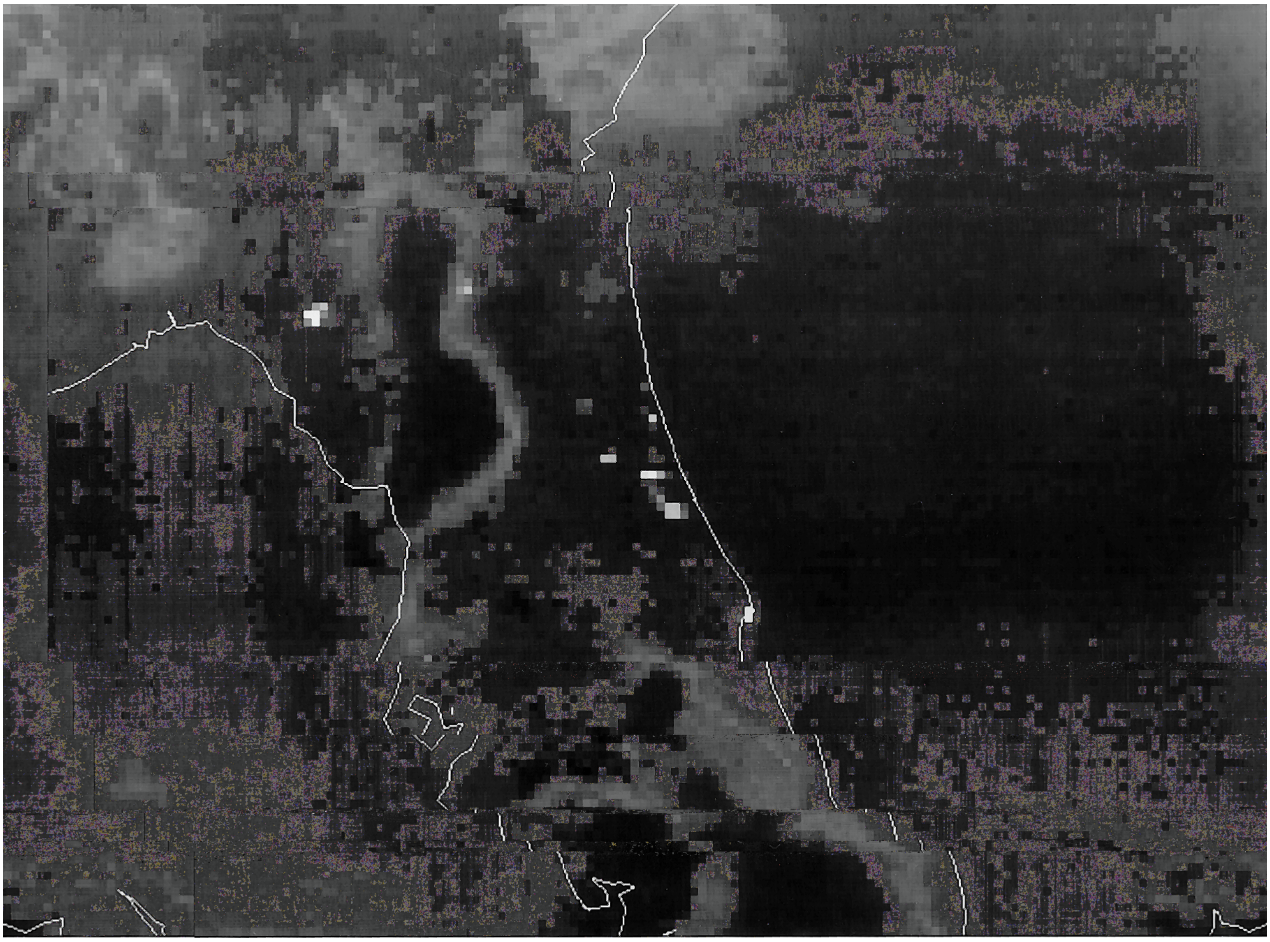

FIG. 4. GOES experimental fire product image taken during the 1998 fire situation in Florida. Note the fires (white spots) in eastern Florida near Daytona Beach and north of Cape Canaveral, and some more tightly grouped fires in the northwestern part of the Florida peninsula.

field experiments and joint research projects with the NWS and other NOAA laboratories.

### a. GOES assessment

RAMSDIS has been integral to the NWS *GOES-8/9/10* Assessment, an ongoing project that began in February 1995. The response from field forecasters on the value of GOES digital satellite data in forecast operations was overwhelmingly positive. Forecasters recommended that RAMSDIS capability be included in AWIPS to maintain the high level of quality in forecasts and warnings (Gurka 1997).

### b. 1996 Summer Olympics

RAMSDIS workstations were installed in Atlanta and Savannah, Georgia, to assist with forecasting efforts for the 1996 Summer Olympics. RAMSDIS, along with the NSSL Warning Decision Support System, formed the core of the warning operations, although forecasters deemed RAMSDIS useful in all meteorological situations (Rothfusz and McLaughlin 1997).

### c. Verification of the Origins of Rotation in Tornadoes Experiment (VORTEX)

The 1995 VORTEX at NSSL was conducted to support ongoing research on several hypotheses concerning the relative importance of various aspects of storm environment in governing or modulating the structure and evolution of tornadic storms. RAMSDIS was utilized extensively during VORTEX for forecasting and for collection of a large volume of satellite data that is being used to support ongoing research.

### d. Lake Effect Snow Study

NWS Central and Eastern Regions RAMSDIS sites participated in the NWS Lake Effect Snow Study to assess the ability of satellite data to augment WSR-88D for lake effect snowband detection, specifically for sites that are outside the optimal winter range of nearby radars (Wagenmaker et al. 1997). The study ran during winter months from 1994 to 1997. Before RAMSDIS deployment, satellite data were ranked last (out of seven) according to utility in short-range (0–6 h) forecasting. After RAMSDIS deployment, satellite data were ranked second to radar and remained that way through the rest of the study.

*e. Lubbock dryline study*

The RAMM–Lubbock FO dryline study was first held in the spring of 1998. Because of the lack of dryline convection that year, the study continued in the spring of 1999. Dryline convection cases were more numerous that year, and RAMSDIS was utilized for convective situation identification, data ingest, and archival and data analysis. Plans are currently being made to coordinate the analysis of the data collected.

*f. Case study of the Moberly, Missouri, tornado*

A joint RAMM–NWS severe weather case study utilized RAMSDIS and corresponding 1-min digital satellite imagery from the CIRA ground station to illustrate how several new modernization datasets could be used in conjunction to provide information on complex storm system formation. The study utilized radar, satellite, model, and conventional data to provide information not available from the individual datasets alone. Browning et al. (1997) illustrate how this combined dataset could be used quickly to view the rapidly changing meteorological environment that led to the tornadoes that formed on 4 July 1995.

RAMSDIS's flexibility has allowed for the development of special workstation configurations to support applications other than forecasting. These special workstations are installed at several NOAA offices and laboratories.

*g. Satellite Operations Control Center (SOCC), Suitland, Maryland*

RAMSDIS is used to monitor and assess GOES image quality (Hillger and Celone 1997). Unlike standard RAMSDIS units, the SOCC RAMSDIS collects and displays information from all five GOES Imager channels, at their maximum spatial resolution. A common-resolution (4 km) sector of the latest images from the five channels is also available for monitoring image alignment. Analysis programs have been developed to measure pixel-to-pixel noise and detector-to-detector striping. Other programs allow the computation and presentation of histogram plots of an individual image and scatterplots of image–channel combinations. In addition to its image monitoring and analysis capabilities for GOES Imager data, the SOCC RAMSDIS also collects and displays images from the GOES Sounder. One set of frames is used to display the most current images from all 19 sounder channels in order to monitor their quality. All analysis programs can be applied to the sounder images as well.

*h. Hurricane Research Division (HRD), Key Biscayne, Florida*

Tropical RAMSDIS was developed at CIRA in 1995 to ingest and display satellite imagery for real-time analysis of tropical weather systems and storms (Zehr 1995). The basic RAMSDIS configuration and procedures were maintained, but significant changes were made to accommodate specialized applications and additional data sources. Rather than being tailored for a specific site, global coverage and movable small area loops are primary features. GOES data are augmented with Geostationary Meteorological Satellite and Meteosat imagery, and user-defined floating sectors can be selected to monitor tropical systems with high-resolution images. Large-scale IR and water vapor loops are also available to allow the analysis of deep convection throughout the Tropics. Since weather observation stations aresparse in the tropical ocean regions, satellite-derived winds, ship/buoy observations, model analyses, and radiosonde information are also part of the Tropical RAMSDIS dataset. In 1996, a Tropical RAMSDIS was placed at NOAA's Hurricane Research Division (HRD). The HRD uses Tropical RAMSDIS to help plan research aircraft missions and to support their overall research goals with archived satellite imagery. The HRD RAMSDIS was recently upgraded in preparation for support of field projects associated with the U.S. Weather Research Program.

*i. Environmental Technology Laboratory (ETL), Boulder, Colorado*

ETL is utilizing a RAMSDIS that receives satellite and ancillary data from the NWS WRH. This includes not only GOES imagery, but some polar-orbiting satellite imagery as well (e.g., special sensor microwave/imager products). The original purpose of the ETL RAMSDIS was to provide real-time *GOES-9* imagery to ETL for the California Landfalling Jets (CALJET) Experiment during the winter of 1997/98. The system is currently used as a real-time ingest and display system, and as an analysis tool for evaluating archived satellite data collected during CALJET. There are also plans to utilize an upgraded RAMSDIS during the Pacific Jets experiment in early 2001.

The low cost, flexibility, and ease of use of RAMSDIS has also made it ideal for joint research projects outside of the United States.

*j. World Meteorological Organization (WMO)*

RAMSDIS workstations have been deloyed as part of joint projects with the WMO in an effort to provide digital satellite data access to developing nations. CIRA supports a demonstration project for satellite-focused Regional Meteorological Training Centers (RMTCs) in Barbados and Costa Rica (Purdom 1997). Both the Costa Rica and Barbados RMTCs have been using RAMSDIS workstations to analyze case study datasets. The Costa Rica site has also been receiving real-time *GOES-8* imagery from the NESDIS server via the Internet. Since the inception of this program, retrospective digital satellite datasets have been provided to both Costa Rica and Barbados. These case studies have been used for training in the use of single- and multichannel imagery in detecting fog, water, and ice cloud, and in the use of applications such as image averaging and determining cloud-motion winds. A real-time ingest RAMSDIS has been installed at WMO Headquarters in Geneva, Switzerland. In support of the Fronts and Atlantic Storm Tracks Experiment, which occurred January–February 1997, a RAMSDIS unit was sent to the European Centre for Medium-Range Weather Forecasts in Reading, United Kingdom, to provide real-time *GOES-8* imagery over the northern Atlantic. Several days of archived *GOES-8* imagery were sent to Reading after the experiment for additional analysis on RAMSDIS. A RAMSDIS workstation is also utilized at the Satellite Meteorology Center in Beijing, China. All international sites are provided with CIRA archived GOES datasets for joint research and local training purposes, including those consisting of 1-min and 30-s scan interval imagery.

## 6. Summary

RAMSDIS quickly gained wide acceptance within the NWS and as of June 1999 was installed at over 60 sites throughout the United States. However, even those numbers to not describe the true impact of the RAMSDIS project because some RAMSDIS sites then posted the RAMSDIS data on servers for access by other Weather and River FOs. Therefore, many RAMSDIS sites became distribution hubs for real-time digital satellite data to other FOs throughout the United States. In addition, when AWIPS deployment began in 1997, FOs receiving AWIPS sent their RAMSDIS workstations to offices that did not have access to digital satellite data, further increasing the early field exposure to the dataset. The response from the NWS forecasters indicates that RAMSDIS

- significantly improved utility of satellite imagery;
- was quickly accepted by staff and became one of the most heavily used systems in the office; and
- provided early exposure, better preparing staff for the integration of digital satellite data into a full workstation capability at AWIPS deployment.

Digital GOES imagery and the analysis capabilities presented by RAMSDIS are having a positive impact across the NWS and into an ever-expanding national and international community. The RAMSDIS project is an example of what can be accomplished with persistence, creativity, vision, and cooperation between various agencies.

## 7. Future directions

While the initial goals of RAMSDIS have been achieved, the RAMSDIS and RAMSDIS Online concepts lend themselves to future activity in many areas. As NWS utilization of RAMSDIS decreases, several new projects are beginning. RAMSDIS functionality continues to evolve to support these new challenges.

*a. WMO expansion*

ROL and RAMSDIS workstations will be deployed at up to 20 Central and South American sites in early 2000 to provide increased access to, and utilization of, digital satellite data in those regions. RAMSDIS workstations will also be installed in Guatemala, Honduras, El Salvador, and Nicaragua in the summer of 2000 to provide access to high-resolution GOES data in the aftermath of Hurricane Mitch. In addition, the RAMM Team has agreed to install workstations in Nairobi, Kenya, and Niamey, Niger Republic, to support WMO training at those locations.

*b. Brazil fire detection*

The RAMM Team is coordinating with the U.S. and Brazilian Forest Services to implement RAMSDIS workstations for use in Brazil fire detection activities. The RAMSDIS systems will provide fire detection products based upon GOES imagery to supplement the current operational products, which are primarily based upon data from polar-orbiting satellites.

*c. NOAA laboratories*

There will be an increased focus on the dissemination of experimental products such as sounder-derived products, AMSU combined products, combined satellite and radar products, and volcanic ash and fire detection products. Data will be made available on NESDIS and CIRA servers for RAMSDIS sites in NOAA research laboratories. As an example, a new version of RAMSDIS has been tailored for the NOAA/NESDIS/SAB (Synoptic Analysis Branch). SAB is responsible for operational, global tropical cyclone center fixes and intensity estimates. They also monitor volcanic ash plumes globally and issue advisories. Specialized satellite products have been added to the new workstation to support these operations. Several NWS RAMSDIS sites have asked to retain their workstations after full AWIPS deployment, making RAMSDIS a potential tool for forecaster evaluation of these experimental products.

*d. Interactive online capabilities*

RAMSDIS Online and RAMSDIS Online Experimental will be expanded to included interactive data analysis capabilities such as digital data and navigation readout. This will provide a powerful training tool that has many applications as an online workstation.

In early 2000, the RAMM Team will begin work to implement a version of RAMSDIS that utilizes McIDAS-X running on Windows NT and on Solaris 7 or Linux PC platforms. However, year 2000 compliant versions of RAMSDIS-OS2 have been completed, and it is anticipated that these workstations will remain in use as long as they are functional.

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