GOES I-M PRODUCT ASSURANCE PLAN

prepared by

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Fourth Version
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FOREWORD

The initial draft of this plan received input from many scientists within NOAA. Contributions from D. Birkenheuer, B. Bryant, D. Chesters, G. Ellrod, T. Fujita, R. Gird, D. Gray, C. Hayden, R. Heymann, F. Holt, E. Howard, G. Hughes, J. Lynch, M. Matson, D. McGinnis, P. Menzel, F. Mosher, A. Mostek, R. Peterson, B. Pichel, W. Planet, J. Purdom, W. Shenk, A. Siebers, R. Scofield, C. Staton, L. Spayd, D. Tarpley, and M. Weinreb. The original version was released 9 November 1992; a second version came out on 25 May 1993, and a third followed on 20 December 1994. This fourth version covers the activities planned for 1996 through 2000.

EXECUTIVE SUMMARY

background

In April 1994 with the launch of GOES-8, NOAA introduced the first in a series of five new geostationary satellites that incorporate a completely new design of three axes stabilized spacecraft, new sensors, and a new ground data processing and distribution system. The launch of GOES-9 followed in May 1995. These new systems have capabilities to support NOAA programs, both operational and research to the year 2000. In particular, the new GOES will support the modernization of the National Weather Service (NWS) and its primary mission of providing warnings and forecasts. "GOES I-M and other new technologies will have an unprecedented impact on Weather Service operations" (Dr. Friday, GOES I-M Operational Satellite Conference, 1989).

purpose of plan

This NOAA GOES I-M Product Assurance Plan is necessary because there have been major changes in the spacecraft and ground systems and their impact on products must be understood. The purpose of the plan is to assure the viability of GOES 8/9 through M day-1 products (equal to or better than the current GOES-7), to improve initial products and develop advanced products, and to ensure integration of the improvements into NWS and National Environmental Satellite and Data Information Service (NESDIS) operations. Product assurance is an ongoing effort and must continue to receive high priority so that the opportunities offered by the new GOES system for supporting NOAA's mission will be realized.

specifics

This plan details the efforts over the next five years that include evaluation and validation of the new GOES-8/9 day-1 products, day-1 product enhancements, user training, and evolution toward future products and sensor systems. Input has been coordinated within NOAA and NASA. Specifically, the GOES I-M Product Assurance Plan

* Identifies the necessary linkages between NESDIS and the NOAA organizational elements using GOES-8/9 through M data, products, and services.

* Defines GOES-8/9 day-1 products, as well as the testing and evaluation necessary to ensure product quality.

* Identifies procedures for user evaluation and feedback.

* Identifies day-1 product improvements and the research and development necessary for advancing to day 2 products aimed at NOAA's high priority cross-cutting programs.

* Defines special satellite schedules that will support NWS operations, national research projects, and integration with WSR88D radar and advanced NWP models.

* Presents a product management structure utilizing the NESDIS Product Oversight Panels and identifies the need for a multi-agency Technical Advisory Committee.

* Identifies an active user training program for the NWS and other users.

* Identifies resources that are needed to carry out this plan.

periodic updates

Efforts are focused on product validation and user training in FY96, technique development toward day-2 products and continued user training in FY97, and new product generation in demonstration mode as well as evaluation and incorporation of new techniques in the subsequent years. The GOES I-M Product Assurance Plan is updated periodically to reflect new information; it is intended to be a working document to assist with planning and resource allocation.

management

The overall management of all GOES I-M product assurance activities resides with the "GOES Program Manager", assisted by a "GOES Scientist" and an "Product Coordinator". The Product Oversight Panels (POP) see to the maintenance and evolution of the products and report to the SPRB (Satellite Products Review Board). A Technical Advisory Committee (TAC) provides guidance regarding priority and feasibility of future products and sensors.

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1. INTRODUCTION

1.1. Planning for Change

early history

Since the early 1960's, meteorological and oceanographic data from satellites have had a major impact on environmental analysis, forecasting and research in the United States and in other nations throughout the world. While polar orbiting satellites provided once or twice daily snapshots of various phenomena, it was not until 1967 that the ability to see weather systems in animation was realized with NASA's geostationary Applications Technology Satellites (ATS). The immediate success of ATS led to the launch of the first operational geostationary satellite with a spin scan stabilized camera in 1975. This evolved to the Geostationary Operational Environmental Satellite (GOES) that carried the VISSR (Visible and Infrared Spin Scan Radiometer), representing a major advancement in our ability to observe weather systems by providing frequent interval visible and thermal infrared imagery of the earth and its cloud cover. Weather systems within the satellites view could be monitored continuously day and night, and GOES data became a critical part of National Weather Service operations by providing unique information about emerging storms and storm systems.

VAS

By the early 1980's, the GOES system evolved to include an atmospheric temperature and humidity sounding capability with the addition of more spectral bands to the spin scan radiometer. This next evolution in the GOES system was termed GOES-VAS, VISSR Atmospheric Sounder. While the addition of channels represented a major improvement in satellite capabilities, instrument design also led to major compromises. Imaging and sounding could not be done at the same time, and a spinning satellite, viewing the earth only 5% of the satellite's duty cycle, makes it difficult to attain the instrument signal-to-noise needed for high quality soundings or the high spatial resolution infrared views of the earth needed to discern clear skies in and around clouds. Recognizing those shortcomings, NOAA began development of its next generation of geostationary satellites, GOES I-M, in 1982.

modern satellite era

The GOES I-M system is a significant advancement in our national geostationary environmental satellite capabilities. All major portions of this system are new: (1) to improve spacecraft instrument performance, the satellite was designed to be earth oriented, i.e. three axes stabilized, so that its instruments could near continuously observe the earth and its cloud cover and not be limited to the 5% duty cycle of the forerunner GOES and ATS satellites; (2) new sensors were designed to improve multispectral imaging capabilities for cloud and storm diagnostics as well as multispectral sensing for atmospheric sounding; (3) the sounding and imaging functions were separated; (4) a new ground data processing system was developed to handle the high volume data that would flow from the satellite and be made into products for a variety of users; and, (5) different data transmission formats were devised for retransmission of raw data to direct receive users.

purpose of plan

This new system must support US geostationary environmental satellite requirements, both operational and research to the end of the 1990's. This plan details a five year program that will ensure that the opportunities offered by the new GOES system for supporting NOAA's mission will be realized. This plan specifically addresses evaluation and validation of GOES-8/9 and subsequent GOES day-1 products, day-1 product enhancements and evolution toward future products and sensor systems. Input has been coordinated with the National Environmental Satellite and Data Information Service (NESDIS), the National Weather Service (NWS), and the Systems Acquisition Office (SAO) in NOAA, and additional information was provided by NASA. A product assurance plan is necessary because of major changes in the GOES spacecraft, data format and ground system with the commencement of the GOES I-M era. The purpose of the plan is to: (1) assure that the GOES-8/9 through M product stream is routinely available and that it continues to improve on what is available from GOES-7; (2) as unique spacecraft

characteristics become understood, enhance the initial product data sets to take full advantage of the new GOES system's capabilities and, (3) utilize the full capabilities of the improved GOES-8/9 data stream to develop advanced meteorological and oceanographic products. This plan outlines an ongoing collaborative effort of NESDIS, NWS, and the Office of Oceanic and Atmospheric Research (OAR) in developing cost effective applications of geostationary remote sensing techniques to support improved atmospheric and oceanic forecasts and services.

1.2   GOES I-M Support of NOAA Missions

NOAA's mission, as detailed in the 1995-2005 Strategic Plan of July 1993, is to promote global environmental stewardship and to describe and predict changes in the Earth's environment. To this end, there are seven high priority programs: (1) build sustainable fisheries, (2) recover protected species, (3) promote healthy coastal ecosystems, (4) modernize navigation and positioning services, (5) implement seasonal and interannual climate forecasts, (6) predict and assess decadal to centennial change, and (7) advance short-term forecast and warning services. These programs are long-term commitments by the entire agency to address urgent problems of national concern. The GOES I-M system is an integral part of NOAA's modernized observing system and is designed to improve NOAA's ability to perform its mission.

As was reported by the Government Accounting Office (1991): "In the early 1980's, the National Weather Service embarked on a broad modernization program to reduce staffing and costs and to improve weather forecasts. Design and production of GOES-Next was a part of this modernization." Among the NWS requirements that impacted the design of the GOES I-M series of spacecraft were:

* independent imaging and sounding
* multispectral imaging with improved spatial resolution
* improved accuracy in atmospheric temperature and moisture soundings
* improved image frame to frame registration accuracy
* long term calibration accuracy
* accurate earth location

The phased implementation of NOAA's modernized observing system has already begun. By the end of this century, the new modernized NWS will be entirely in place. This will include GOES and NOAA satellites, WSR88D (Doppler) weather radars, wind profilers, automated surface observing stations (ASOS), and winds and temperatures along commercial aircraft routes (ACARS). Observational data, such as GOES images, will be automatically displayed on the Advanced Weather Interactive Processing System (AWIPS) in order to improve the flow of information to the forecaster. To ensure GOES data and imagery make an important contribution to the modernized NWS, the NWS has required these data to be precisely navigated, calibrated, remapped and distributed quickly. New products will need to be developed that rely on information from the partnership of these high technologies that will accompany NWS modernization.

The following paragraphs are taken from the presentation of Dr. E. W. Friday, Assistant Administrator for Weather Services, at the GOES I-M Operational Satellite Conference held April 3-6, 1989 in Arlington, VA. These comments from the previous decade still best summarize the expectations of the NWS regarding the GOES I-M system of instruments.

"Geostationary satellites provide a unique instrument platform for obtaining information and coverage that encompasses all ground based observations. GOES I-M will provide many times more visual information

than GOES-7 does today, and with added communication capacity, GOES I-M will provide access to observations from thousands more environmental data platforms. ...

Mesoscale analysis and forecast concepts of the 1990's demand knowledge of storm environment parameters, such as local terrain effects, local low level moisture and vertical wind shear gradients, as well as the detection and tracking of unstable air mass boundaries, previous storm outflow boundaries, and the onset of convection. Geostationary satellite based imagery and sounding products with mesoscale location accuracy will have the opportunity to make a critical contribution to the warning and forecasting of hazards associated with convective storms.

Dr. Friday's comments

GOES I-M observations will provide the forecaster with initial indications of the rapid development of convection. This is especially important in the mountainous west where radar coverage is severely restricted by terrain features. The improved temperature sensitivity for earth surface temperatures will allow meteorologists to more accurately determine the position of surface boundaries, such as dry lines that neither the radar nor surface data will adequately detect. Subsequently, using the GOES I-M imagery, the forecaster could more precisely delineate the formative areas of convective activity than is possible today.

A valuable tool in today's flash flood program is the ability to estimate rainfall amounts in data-sparse areas from satellite imagery. With improved earth location capability and greater IR temperature sensitivity, the satellite-derived rainfall estimates will be much more useful in flash flood prediction than those generated today.

Another valuable aspect of GOES I-M is the ability to produce satellite derived atmospheric sounding at frequent intervals. This feature will enable the meteorologist to locate areas of decreasing stability enhancing the ability to predict and subsequently alert the public as to the potential of severe storms. ...

The hurricane program will also benefit from GOES I-M products. Limited aircraft reconnaissance resources will continue to result in requirements for monitoring by satellite, the genesis, evolution, and track of hurricanes and tropical cyclones at sea. Improvements in the infrared image resolution are expected to help with nighttime tracking of the hurricane centers and changes in the storm's strength.

Large scale analyses and model output are used to forecast the future path of tropical cyclones. Conventional observations are few over the oceans and therefore, satellite imagery and derived products provide important information for depiction of weather in the analyses and model initialization fields. Improvements in image registration and location accuracy will contribute directly to improved synoptic scale tropospheric flow and storm environment wind analyses. In addition, soundings of the storm's eye have the potential for making significant contributions to estimates of storm intensity."

In anticipation of the GOES I-M system's impact on NWS Modernization, Dr. Friday added: "The new GOES I-M system is designed to make a significant contribution to our knowledge of the state of the atmosphere and how it is changing with time, ultimately leading to an improved warning and forecast process. The value of GOES I-M technology to the warning and forecast program will be fully realized when forecasters are efficiently using the data and products with other observations and in numerical forecast models to improve weather operations and services." The effort outlined in the previous GOES I-M Product Assurance Plans (GIMPAP) as well as the update in this fourth GIMPAP assures that the capabilities of the GOES-8/9 system will be fully exploited and the actions necessary to realize the anticipated improvement in NWS products and services will be initiated.

Realization of expectations

New data processing systems have been developed to accommodate the new opportunities offered by GOES-8/9; an expanded NESDIS day-1 product suite is coming on line (the current list is summarized in Appendix C). New data processing and analysis systems are being placed at NWS National Centers (Meteorological Interactive Data Access Systems) and field offices (Advanced Weather Information Processing System) that will make it possible for the first time to exploit the full potential of a frequent interval observing system from geostationary satellites.

plan for next 5 years

Establishing the means and methods of effectively integrating GOES I-M into operational service programs requires the coordinated and combined efforts of research, development and operational units within NOAA over the next 5 years (FY 96-00). This period covers the evaluation for the NWS Modernization and Restructuring (MAR) and the introduction of GOES-8 and -9 into operations. The new and improved products and services from the new GOES satellites are expected to make an important contribution to a number of important national programs. Foremost, among them, are NOAA's five high priority cross-cutting programs.

1.3. Major S/C and Instrument Change

comparing to GOES-7

Responding to user requirements for improvements in the GOES-VAS system, several instrument and spacecraft changes evolved with the GOES I-M program. Specifications called for performance improvements over GOES-7 (VAS) by factors of 2 to 4 in signal-to-noise and spatial resolution. This resulted in a different platform: a 3-axes earth-staring design, instead of the previous spin-scan design. This basic spacecraft design change leads to completely different scanning, navigation, calibration and thermal-control systems, with corresponding impact upon meteorological data products.

ongoing instrument characterization

The impacts of these differences on data quality and the ability to generate high quality products must be evaluated and assessed, and where the need arises fixes must be made. The delicately balanced navigation and calibration systems on GOES-8 experience many periodic diurnal and annual forces that require ongoing characterization of instrument performance and the effect on products.

separate imager and sounder

The GOES I-M requirements resulted in separate sounding and imaging instruments that can be operated independently, improved IR resolution, 5 channels of image data, and 19 channels of sounder data. As a result a new data transmission format was devised to allow the GOES I-M data user to receive simultaneous operational data from the imager and the sounder, instead of alternately and experimentally as on GOES-7. Section 3.1.2 contains a summary of the expectations of GOES I-M versus performance of GOES-7 (VAS) with regard to radiometrics and navigation.

improved imager

The GOES I-M imager provides visible data with the same 1 km resolution as GOES-7, but with a stable linear response and precision to 1 part in 1024, instead of a variable nonlinear response to 1 part in 64. Imagery is to be earth-navigated within 1-2 km instead of 3-10 km, by

using star positions in addition to traditional landmarks. The imager also provides continuous infrared imagery simultaneously in four thermal channels, instead of the two or three channels available from the GOES-7. All but one of the GOES I-M imager infrared channels are at 4 km horizontal resolution instead of 8 km. On-board calibration is to provide brightness temperatures with 1.0 K absolute accuracy and 0.3 K relative precision, and noise levels reduced 2 to 5 times over GOES-7.

operational sounder

The GOES I-M sounder provides 18 thermal infrared channels plus a low-resolution visible channel, instead of the 12 infrared channels with visible on GOES-7. Several of the new channels are sensitive to temperature, moisture and ozone at wavelengths never before used in geosynchronous orbit. The GOES I-M sounder's design goal is to provide brightness temperatures with 1.0 K absolute accuracy and 0.3 K relative precision, and noise levels reduced 2 to 10 times over GOES-7.

1.4   Purpose of Product Assurance Plan

The purpose of the NOAA GOES I-M Product Assurance Plan is to assure the viability of the new GOES day-1 products, to improve initial products and develop advanced products, and to ensure integration of the improvements into NESDIS and NWS operations. These efforts will make the new GOES capabilities available to both public and private sector users in an efficient, effective and timely manner.

Other NESDIS GOES I-M project plans detail post launch data checkout (e.g. the Operational Ground Equipment (OGE) checkout plan has been written by the GOES I-M Ground Systems Project) and production of the initially defined day-1 products (e.g. the software implementation plan is being written by the Satellite Services Division). Other NOAA programs have plans to use and archive the new GOES data and products. This plan presents the procedures and plans relevant for GOES-I data and products in three key areas:

3 key areas of product assessment

* scientific evaluation;
* user assessment;
* product evolution.

Since the organizations involved are part of several NOAA Line Offices (LO), the process for accomplishing this is complex. For this reason priorities for the integration of GOES I-M into NOAA programs are established at the Assistant Administrator level to assure that appropriate resources are made available to accomplish the ongoing assessment with additional money available for new product development and training. Specifically this plan:

* Identifies the necessary linkages between NESDIS and the NOAA organizational elements that will use or benefit from GOES I-M data, products, and services.

need for high priority

* Defines GOES-8 day-1 products and services, the testing and evaluation procedures necessary to ensure day-1 products are of a quality at least comparable to GOES-7, and identifies responsible parties.

* Identifies day-1 product improvement and the necessary development activities that lead to advanced day 2 products aimed at NOAA's high priority cross-cutting programs.

* Defines special satellite schedules that will support NWS operations, national research projects, and integration with WSR88D radar and advanced NWP models.

* Identifies procedures for user evaluation and feedback.

* Presents a product management structure utilizing the NESDIS Product Oversight Panels and identifies the need for a multi-agency Technical Advisory Committee.

* Identifies user requirements for data and product documentation and plans an active user training program.

* Identifies resources that are needed to carry out this plan.

periodic updates
to plan

This plan is updated periodically to reflect new information. This is the third version (second update from the original). Section 2 reveals the strategy for product assurance, while section 3 presents the testing and development activities in some detail. Section 4 indicates how the integration into operations will occur. Section 5 discusses the evolution to improved products and instruments. Appendix A indicates the government and university laboratories plus the resources that will be required to assure effective utilization of GOES-8 products and services. Appendix B outlines the management plan. Appendices C and D list the products and the individual responsible for product assurance. Appendices E and F list available references and planned information documents and related activities. Appendix G describes the operational GOES-8/9 schedules. Appendix H details a training plan for the NWS and other users. An acronym list occupies Appendix I.

2.   STRATEGY FOR PRODUCT ASSURANCE

2.1.   Product Quality

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evaluation criteria

There are two basic categories of products provided to the user community: (1) data, such as a raw satellite image or image loop animation; and (2) derived products, such as winds, soundings and combined radiometric products. Product quality is measured relative to:

* past levels of performance for GOES-7;
* specified performance requirements for GOES-8/9
      (as indicated in the NWS GOES-NEXT Requirements, 1983);
* user response.

2.2.   Post-launch Checkout

The NASA GOES Project conducted post-launch evaluations of system performance with respect to a number of parameters (e.g. calibration, navigation, registration) crucial to successful product generation. In addition, product assurance required special modes of instrument operation and acquisition of ancillary data from selected platforms such as the NOAA demonstration profiler network, next generation radar, model output, aircraft remote sensing, polar satellite data, and other geostationary satellite data (more details are provided later in this plan). GOES-8/9 data quality was found to have exceptional quality (see section 3) and GOES-8/9 products have compared favorably to those from GOES-7. Assimilation of GOES-8/9 products with other available sources of information is being done to reveal the impact of those products (e.g. soundings with radiosondes and model predictions). These activities began during the intensive post-launch instrument checkout period of six months and the satellites commissioning; they continue during routine operations to accommodate annual characteristics of the spacecraft and instrument performance.

GOES-8 checkout

2.3.   Evolution of Products

algorithm adjustment

The preparation for day-1 products involve direct cooperation of algorithm developers with users in the NWS; this includes users both at the National Centers and the local Forecast Offices. Efficient feedback mechanisms are mandatory so that the product can quickly evolve and achieve acceptance. The routine operational schedules provide the necessary data flow for evaluation. After the initial algorithm adjustment that comes from experience with actual data, operational turn on of the day-1 products are the responsibility of the Product Oversight Panels; Appendix B suggests a management hierarchy and a template for a detailed management plan for each product.

The evolution to day-2 products depends on experience with day-1 products and scientific developments through case studies. The scientific checkout of GOES-8/9 was the primary opportunity for more ambitious data gathering (e.g. very rapid interval imaging and sounding). The case studies developed with these data are the focus of considerable scientific endeavor. Other special research opportunities with GOES-8/9 center around the field experiments planned (for example the Lake Effect Snow Experiment); these will provide additional case studies for evolution to day-2 products.

3. EVALUATION/VALIDATION

Evaluation/validation of instrument performance, image quality, and imager and sounder products ensure that NOAA realizes improved services through the effective use of the new remote sensing capabilities provided by the new GOES satellite series. The characterization of instrument performance is accomplished largely through the efforts of the NASA GOES Project with NOAA participation from NESDIS, NWS, and SAO. The product assurance through evaluation and validation efforts is accomplished largely within NESDIS, NWS, and ERL with university collaboration. Overall supervision is accomplished by the "GOES Program Manager" with assistance by an "Office of Research and Application (ORA) GOES Scientist" and an "Office of Satellite Data Processing and Distribution (OSDPD) Product Coordinator". As the products become mature and operational, the responsibility for maintaining and improving the products resides within the Product Oversight Panels (POPs) of NESDIS. Appendix B presents more details.

supervision

An ongoing effort is anticipated. The five years outlined in this plan consist of data collection, technique development, product validation, and user familiarization in the current year; further technique development, new product generation, and demonstration periods for the NWS in the second year, and evaluation and incorporation of new techniques in the subsequent years.

ongoing effort

3.1. Characterizing and Validating of Instrument Performance

Instrument performance is being evaluated through a close working relationship between the NASA GOES Project and the office of the GOES Program Manager using the structure outlined in Appendix B. The NASA GOES Project post-launch evaluation of the instrument focused on adequately characterizing performance against specified performance levels. The GOES-8/9 data are still being compared against data from the VAS (VISSR Atmospheric Sounder) on GOES-7 and the HIRS (High resolution Infrared Radiation Sounder) and the AVHRR (Advanced Very High Resolution Radiometer) on the NOAA polar orbiting spacecraft by the scientific user community. The radiometric quality is being analyzed and catalogued by the appropriate Product Oversight Panels.

comparison with other geo and leo instruments

GOES-8/9 is a totally new system whose behavior was carefully assessed. The delicately balanced navigation and calibration systems are experiencing many periodic forces, such as high frequency modes associated with scanning, diurnal modes associated with earth-facing operation, annual modes associated with insolation on the "north polar cap" detector cooler plates, and beginning-of-life and end-of-life modes associated with outgassing and component degradation. Analyses to determine impacts on product quality as a function of diurnal changes, seasonal changes, and spacecraft aging are continuing throughout the lifetime of the spacecraft.

diurnal and seasonal changes in performance

3.1.1 Imager Performance

The GOES-8 and -9 imagers are exceeding radiometric requirements; there are some line-to-line, channel-to-channel and scene-to-scene brightness variations in the calibration, but they are comparable to those experienced with GOES-7. The principle radiometric error is due to the random zero-point drifts for a few seconds between space-looks, due to the lack of an infrared chopper in the GOES-8/9 imagers.

Inflight determinations of noise levels that all bands on the imager are meeting spec. The following table indicates the in flight noise performance of the GOES-8 and -9 imagers versus GOES-7 and Meteosat-5; noise in GOES-8/9 data has been reduced by factors of 2 to 20 over that in GOES-7 data.

The improved performance is most notable in the visible band, where 10 bit data from silicon detectors shows much better dynamic range and detector to detector consistency. The water vapor band performance of GOES-8/9 is improved by more than an order of magnitude over GOES-7; this brings GOES-8/9 in line with the very good noise performance of the Meteosat-5 water vapor band. GOES-8/9 water vapor images are noticeably sharper than those from GOES-7. The high spatial resolution and the good signal to noise of the imager data also make it very useful at satellite viewing angles up to 75 degrees.

Table: GOES-8/9, GOES-7, Meteosat-5, and GMS-5 Imager Comparisons of Inflight Performance (with GOES-8/9 specified noise values indicated)

Band	Bit Depth	Resolution	Noise
imager performance	G9 /G8 /G7 /M5 /G5	G9 /G8 /G7 /M5 /G5	G9(spec)/G8 /G7 /M5 /G5
Visible			counts
.65 um	10 / 10 / 6 / 8 / 6	1 / 1 / 1 / 2.5 / 1.25 km	3 (7) / 3 / 1 / 1 / 1
Infrared			(deg C at 300 K)
3.9 um	10 / 10 /10 / X / X	4 / 4 / 16 / X / X km	.12(1.4) / .23 / .25 / X / X
10.7 um	10 / 10 / 10 / 8 / 8	4 / 4 / 8 / 5 / 5 km	.09(.35) / .14 / .15 / .20 / .11
12.0 um	10 / 10 / 10 / X / 8	4 / 4 / 16 / X / 5 km	.19(.35)/ .26 / .40 / X / .13 (deg C at 230 K)
6.7 um	10 / 10 /10 / 8 / 8	8 / 8 / 16 / 5 / 5 km	.11(1.0) / .22 / 1.0 / .40 / .40

The GOES-8/9 imagers are close to meeting their pointing requirements over the continental United States (CONUS) sector; various motion compensations are working well. The GOES-8/9 image navigation system are providing good earth location so that the imagery can be remapped with confidence; improved algorithms and short span attitude adjustments have improved the performance so that the 4 km navigation from frame to frame is being met more than 90% of the time.

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3.1.2 Sounder Performance

The GOES-8/9 sounders are exceeding their radiometric noise requirements in the shortwave and midwave channels, and they are below requirements in the longwave channels. Calibration performance is meeting requirements because the short-term random drifts in the sounder's infrared signal are suppressed by frequent looks at the filter wheel housing (performing the function of beam chopping).

Table: GOES-8/9 Sounder Comparison to GOES-7 VAS and NOAA-12 HIRS

Wavelength (um)	Ch	NEDT G-9 (290K)	NEDR G-8 (mW/m2/ster/cm-1)	G-9	(spec)	G9/G7 (FOV adjusted)	G9/N12
Longwave							
14.7	1	0.75	1.63	1.20	(0.66)	0.13	0.84
14.4	2	0.49	1.41	0.80	(0.58)	0.18	0.75
14.1	3	0.36	0.94	0.56	(0.54)	0.40	0.85
13.9	4	0.28	0.65	0.46	(0.45)		1.03
13.4	5	0.27	0.74	0.45	(0.44)	0.32	1.06
12.7	6	0.12	0.32	0.19	(0.25)	0.17	
12.0	7	0.08	0.21	0.13	(0.16)		
Midwave							
11.0	8	0.07	0.15	0.10	(0.16)	0.76	0.47
9.7	9	0.07	0.20	0.11	(0.33)		0.35
7.4	10	0.09	0.091	0.076	(0.16)		0.18
7.0	11	0.07	0.091	0.047	(0.12)	0.04	0.12
6.5	12	0.15	0.119	0.086	(0.15)	0.33	
Shortwave							
4.57	13	0.09	0.012	0.008	(0.013)		0.63
4.52	14	0.08	0.011	0.007	(0.013)	0.13	1.10
4.45	15	0.08	0.012	0.006	(0.013)	0.09	0.71
4.13	16	0.08	0.004	0.003	(0.008)		
3.98	17	0.10	0.005	0.003	(0.008)	0.21	0.71
3.7	18	0.05	0.002	0.001	(0.004)		0.47

FOV sizes

GOES-8/9	8 km
GOES-7	7 km (14km for very longwave and shortwave)
HIRS	17 km

The GOES-8/9 sounder pointing accuracy requirements are not as stringent as those of the imager, and are being met by the same high precision star-tracking methods used with the imager. Channel-to-channel registration has been difficult to achieve in the GOES-8 sounder's multi-beam design; it remains an area of some concern.

sounder performance

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3.2. Evaluation/Validation of Derived Products

3.2.1. Calibration

The calibration algorithm of the infrared radiances is being validated as part of the scientific evaluation. To validate the IR radiances, the GOES-8 measurements are being compared to collocated radiance measurements from other sensors (on board the geostationary GOES-7 and Meteosat as well as the polar orbiting NOAA series) and with forward calculations based on radiosondes or model analyses. Diurnal and seasonal changes in the infrared calibration are under investigation by the NESDIS Satellite Operations Control Center (SOCC) with assistance by the Physics Branch. Additionally, a relative calibration of the visible detectors is being done routinely over the life of the spacecraft to correct for long-term sensor drift. The techniques in use for the AVHRR Pathfinder activity, using periodic measurements of a desert whose reflectance is assumed constant in the long term, are applied to the GOES I-M visible data. A target data base has been developed that will supply the data arrays (daily, hourly, seasonally) for selected sites that will serve for the visible calibration. The utility of bright clouds for visible reference is also under consideration. The NESDIS Physics Branch is assuming responsibility for the visible calibration. The Calibration Oversight Panel coordinates these activities.

SOCC investigating calibration trends

3.2.2. Navigation

The navigation of GOES-8 images is under evaluation through deviations in landmark registration; these are catalogued diurnally and seasonally, with corrections suggested to the Operational Ground Equipment periodically. The Navigation Oversight Panel coordinates this activity.

OGE navigation corrections

3.2.3. Image, Cloud, and Aerosol

Activities in this area are coordinated through the Image, Cloud, and Aerosol POP.

The GOES-8 imaging system has the capability of providing a wider variety of image products. The five imager channels are:

> (1) .55-.75 um (vis) used for imaging clouds, snow and ice, and land features:
>
> (2) 3.9 um (shortwave infrared window) used for identifying fog/stratus, cloud vs snow, fires/volcanoes, and sea surface temperature (SST) determination:
>
> (3) 6.7 um (water vapor channel) used for synoptic analysis, upper tropospheric humidity, and finding convection:
>
> (4) 10.7 um (longwave infrared window) used for cloud tracking, locating cloud tops, and SST determination: and,
>
> (5) 12.0 um (split window) used primarily for low level moisture identification and SST determination.

5 imager bands

Facilities with direct receive capabilities such as the NWS National Centers (the National Severe Storm Forecast Center (NSSFC), the National Hurricane Center (NHC), the National Meteorological Center (NMC)), NESDIS, the Forecast Systems Laboratory (FSL), the Cooperative Institute for Research in the Atmosphere (CIRA), and the Cooperative Institute for Meteorological Satellite Studies (CIMSS) can receive OGE calibrated and navigated data directly through the GVAR data stream. At NESDIS, GOES-8 images are produced in either full disk,

partial disk or sectorized format for transmission to field users. There are two basic image formats: (1) the GOES projection for transmission over the existing GOES-TAP and FAX/WEFAX system; and, (2) remapped imagery to be made available to the National Weather Service (NWS) via a new mode to be known as GOES I NOAA-PORT Interface (GINI). Although AWIPS is not implemented for the first years of GOES-8/9, some facilities are in place to evaluate the GINI products.

image formats

GOES-TAP

GOES-TAP and FAX/WEFAX images closely resemble those produced for GOES-7. The sectors cover areas with equivalent resolutions of 1 km, 4 km and 8 km. The sectors are about 32% larger in area than those for GOES-7, in order to maintain the same data format for transmission to existing facsimile equipment, this results in a slight reduction of the maximum resolution normally available. Although five image channels are available from GOES-8/9, only three are planned for day-1 transmission on the GOES-TAP system, along with one composite type image (e.g. combined visible and infrared window image). The same limitation of image frequency now existing (30-minute interval) will still apply.

enhanced images

Enhancement of the imagery is provided, based on user requirements. Evaluation of GOES-8 enhanced data sets continues. Diurnal or seasonal characteristics of GOES-8/9 data require several versions of a given enhancement curve to be available so that the outgoing data can be adjusted in such a way that observed changes are not an artifact of the satellite sensors. Further work is needed to include multispectral products. Several multispectral products, particularly those using the 3.9 um channel are being developed and may be viable in the near term for application to volcanic ash cloud monitoring, tropical storm eye locations, aviation forecasting, etc. Work in these areas continues at CIRA and the Physical Sciences Branch.

AWIPS

Plans are that image sectors for the AWIPS system will be produced for the continental US (one eastern and one western) and for the Hawaii, Puerto Rico and Alaska forecast areas. AWIPS imagery will be remapped into a Lambert Conformal projection for most sector types, except for Alaska sectors that will be in the Polar Stereographic projection. All image channels plus 3 composite images will be available at any time at full resolution. From the full resolution sectors, individual AWIPS sites will extract sectors for larger scale applications (full sector), regional scale applications (2000 or 1500 km by km sectors), or local scale applications (750 or 500 km by km sectors). The frequency of these images depends on the mode of GOES operation.

schedules

Three operating scenarios are planned: Routine and Warning and One-minute. In the Routine mode most imagery will be produced at 15 minute intervals. In the Warning mode, image frequency increases to four times per half hour. Full earth disk imagery will be available every 30 minutes during Routine mode operations but will be reduced to 3 hourly intervals in the Warning mode. The latter time interval is the minimum required by international agreement. It is required that at 6 hourly synoptic times, a sequence of three consecutive full disk images will be needed for producing global winds for inclusion in numerical models. The One-minute mode is called for special observations of rapidly developing weather; one minute interval images cover half of the CONUS and occur in 20 minute segments to accommodate northern hemisphere coverage every half hour.

east-west composites

In the AWIPS era, imagery from GOES-East and GOES-West will be combined into one polar stereographic image covering most of the northern hemisphere. The images will be produced in three separate channels; visible, infrared window, and water vapor. Each image pixel will consist of an average brightness over an 8 km x 8 km area. This new day-1 product will not be available during the Warning Mode.

RAMSDIS

While awaiting full implementation of AWIPS, a number of RAMSDIS units have been distributed to enable access to digital GOES-8/9 data via internet from NESDIS. The purpose of RAMSDIS is to provide enhanced satellite imagery and products to Weather Service Offices on a system capable of assessing their quality. RAMSDIS activities are centered on: a) familiarizing NWS offices with digital satellite data; b) establishing base-line training needs at NWS for using digital satellite data; c) enabling more effective use of AWIPS at NWS field offices when it arrives; and d) improving the utility of satellite imagery and derived products. RAMSDIS provides additional image analysis capabilities; interrogation and display of digital data ; access to imagery with increased spatial resolution and bit depth; half-hourly display of multiple products (or rapid scan images when scheduled); site specific modifications with image centering and special grids (including WSR88D range marks on the imagery); and, several user friendly specific applications. navigation on image loops. Schedules of images and derived products vary from site to site to accommodate local needs. Initial response to these units has been uniformly positive; some 60 RAMSDIS units will be deployed prior to AWIPS.

image evaluation

The imagery transmitted through GINI and GOES-TAP are being used for individual picture interpretation (e.g. cloud type identification, fruit frost forecasts) and for observing changes in weather systems with animated image sequences (e.g. thunderstorm development, vorticity center location). CIRA is conducting image evaluations of GOES-8/9 and NOAA AVHRR capabilities to identify features; they have developed algorithms for the comparison of these imagery. NSSFC, NHC, and selected WSFOs will be evaluating the quality of the imagery for their specific concerns. Additionally, FSL is evaluating GOES-8 satellite imagery in its hourly Local Area Prediction System (LAPS).

Specific areas of investigation include:(1) diurnal and seasonal characterizations; (2) comparison of 6 and 10 bit visible imagery; (3) low light visible capabilities; (4) image clarity; (5) near spacecraft midnight effects on imagery; (6) effects of within frame registration errors and jitter on computer animated loop analyses; (7) investigation of combined image products, such as the CIRA developed combined vis/IR imagery; and (8) evaluating the utility of the different spectral band applications.

day-2

In preparation for day-2 enhancements, CIRA is also studying cloud height assignment from shadows and stereographic techniques. Additionally, multispectral techniques to identify cloud phase are under investigation and will also be done with the sounder. The Physics Branch, in response to a request from the NWS Office of Hydrology, is developing an operational insolation product for the CONUS using the visible data; a focus on insolation and albedo in the Mississippi drainage basin is expected in 1996. Other day-2 products, either planned or under investigation, are given in section 5.4.

ASOS cloud product

CIMSS and the Physical Sciences Branch have developed and validated a GOES-8/9 cloud product through comparison with ground observations with NWS participation. The GOES-7 algorithm has been adjusted to accommodate the GOES-8/9 observing characteristics and is being adapted for imager use as well. This cloud activity is motivated by the NWS introduction of the Automated Surface Observing System (ASOS) nationwide; there already are a limited number of ASOS sites in the midwestern United States. ASOS uses automated equipment to provide near continuous observations of surface weather data including cloud height and amount that are currently obtained by NWS observers. The cloud information from the ASOS equipment is limited to altitudes below 12,000 feet, thus the GOES-8 will be expected to provide supplemental information about cloud cover above 12,000 feet. The combined ASOS/satellite (ASOS/SAT) system is expected to depict cloud conditions at all levels. Because observations are required every hour, the satellite cloud product must be derived from the geostationary spacecraft data. The satellite cloud information is derived using sounder data with the CO_2 slicing

technique or imager data using the H2O intercept technique, which calculate cloud top pressure and effective amount from radiative transfer principles. It also reliably separates transmissive clouds that are partially transparent to terrestrial radiation from opaque clouds in the statistics of cloud cover. For a given ground observation site, the algorithm uses radiation measurements from an area of roughly 50 km by 50 km centered on the site.

Several WSFOs are participating in the GOES evaluation and validation. The NWS WSFO at Milwaukee/Sullivan is participating in the evaluation/validation of the ASOS/SAT system. There are already ten ASOS units installed in Wisconsin and the Milwaukee/Sullivan WSFO has already been involved in the first steps of the local ASOS augmentation tests. The Milwaukee/Sullivan WSFO is working with CIMSS, the developers of the satellite technique, to provide a local evaluation. CIRA is engaged in similar activities with the Cheyenne WSFO. Several NWS sites are participating in the Lake Effect Snow Experiment to investigate lake effect snow associated with the Great Lakes in the Midwest; these offices have RAMSDIS and are coordinating evaluation activities with CIRA.

3.2.4.   Soundings

There are several GOES products that come under the category of soundings. From the sounder, they include the clear field of view (FOV) brightness temperatures, profile retrievals of temperature and moisture, as well as their layer mean values, lifted indices, and thermal wind profiles. Additionally from the imager, there are derived product images of precipitable water and lifted indices. The Soundings POP coordinates activities in this area. A brief description follows.

Vertical temperature profiles from sounder radiance measurements are produced at 40 pressure levels from 1000 to 0.1 mb using a simultaneous, physical algorithm that solves for surface skin temperature, atmospheric temperature and atmospheric moisture. Also, estimates of surface emissivity and cloud pressure and amount are obtained as by products. The retrieval begins with a first guess temperature profile that is obtained from a space/time interpolation of fields provided by the NWS forecast models. Hourly surface observations are also used to provide surface boundary information. Soundings are produced from a 5x5 array of FOVs whenever 9 or more FOVs are determined to be either clear or "low cloud". The FOVs are "cloud filtered" and co-registered to achieve an homogeneous set. The location (latitude and longitude) of the retrieval is assigned to the mean position of the filtered sample. A "type" indicator is included in the archive to indicate if the sounding represents "clear" or "low cloud" conditions. A quality indicator is included to indicate if the retrieval has failed any internal quality checks.

Vertical moisture (specific humidity) profiles are obtained in the simultaneous retrieval, and thus are provided at the same levels as temperature up to 100 mb. Since the radiance measurements respond to the total integrated moisture above a particular pressure level, the specific humidity is a differentiated quantity rather than an absolute retrieval. Geopotential height profiles are derived from the full resolution temperature and moisture profiles. Layer means of either temperature or moisture can also be derived (although there are no plans to do so presently). Layered precipitable water may be integrated from retrievals of specific humidity. Only the total precipitable water is provided in the standard archive.

The channel brightness temperatures for the available channels are archived with each retrieval. These values are filtered from the 5x5 arrays of FOVs used to produce a single retrieval. Only heterogeneous cloud contamination is removed. The values are not limb corrected, nor has solar contamination (if present) been removed. The brightness temperatures may represent either "clear" or low "uniform cloud" conditions.

LI

The lifted index for each retrieval is also derived. The lifted index is an estimate of atmospheric stability. It represents the buoyancy that an air parcel would experience if mechanically lifted to the 500 mb level. The lifted index expresses the difference in temperature between the ambient 500 mb temperature and the temperature of the lifted parcel. A negative value (warmer than the environment) represents positive buoyancy (continued rising); whereas a positive value denotes stability (returning descent). The formulation used to derive LI is a thermodynamical relationship requiring the 500 mb temperature and a mean pressure, temperature, and moisture for the boundary layer. These quantities are all available from the retrieved profile

z

The geopotential height of the pressure level as derived from a 1000 mb height analysis (from the NMC forecast supplemented with hourly data), a topography obtained from a library (10 minute latitude/longitude resolution) and the retrieved temperature and moisture profile are contained in the archive of each retrieval. Thickness can be calculated from this profile.

gradient winds

Thermal winds are provided with each profile. These are derived from objective analyses of the geopotential profiles calculated with each retrieval. The objective analysis is a 3-dimensional, univariate recursive filter that uses as a background the same fields that provide the first guess to the temperature retrieval algorithm (NMC forecasts and surface analyses). The analyses are performed on a 1 degree latitude/longitude grid. Gradient winds are calculated using finite difference operators that involve surface-fitting over 5x5 gridpoints centered at the gridpoint closest to each retrieval. Wind estimates are provided from 700 to 400 mb. Verification studies with observed winds have shown that this product from VAS depicts the temperature gradient consistently more accurately than the NMC forecast. It will be verified that the GOES-8/9 product is even better, and with expanded geographical coverage.

derived product imagery

Derived product imagery can be produced from either the imager or the sounder. Data from the former is limited to the longwave split window, the shortwave window, and the 6.7 um water vapor channels. However, the day-one GOES-8/9 derived product imagery, total precipitable water and lifted index, can be produced using only these channels with acceptable results. Derived product imagery is formed from pixel-by-pixel retrievals of atmospheric temperature and moisture profiles wherever the atmosphere is quasi-clear. The derived product is scaled to the major part of the 6-bit quantization of the image area. The high order bits of the image are used to store "bright" 11 um window values when cloud contamination is sensed. Thus the images appear as the derived product with the cloud cover superimposed. A major effort of the early GOES-8 derived product image evaluation is to determine if the multiple bands of the sounder offer a significant improvement over the imager.

The day-1 derived product images are total precipitable water in the atmosphere, a standard retrieval product adapted to the image format, and an additional image of the lifted index. It should be added that the processing software has provision for a third derived product image that may be defined during the evaluation.

product assurance

Product assurance with regard to soundings is coming from the following activities. During the post-launch checkout period (1) collection of all satellite data and generation of products with existing algorithms to evaluate their performance, (2) development of improved algorithms for selected case study days utilizing the new spectral capabilities of the GOES-8, and (3) investigation of methods to determine the boundary layer temperature and fluxes. These activities are focused at CIMSS, while selected investigations such as sounding via radiance clustering and structure function analyses are being undertaken at CIRA. It is anticipated that the data collection period for the evaluation will overlap with several special field programs (e.g. the U. S. Weather Research Program) so that the extensive ground based profiler and special sonde network will be available for intercomparison and assimilation.

1995

Hourly processing of the sounding and imaging data started in 1995. Derived product images of layer mean temperature and moisture as well as surface skin temperature and cloud top pressure are being displayed on the CIMSS home page. In January 1995, the NASA ER-2 high altitude aircraft was flown to obtain high spectral resolution data with the High resolution Interferometer Sounder (HIS) for comparison with the GOES-8 imager and sounder radiances. Calibration of the imager window channels proved to be better than .3 C; comparisons for the sounder are still under investigation.

1996

In 1996, the effort on soundings will focus on inclusion of GOES-9 soundings to form composite sounding fields from GOES-8 and -9 and collaboration with NCEP to conduct model impact studies. GOES 8/9 data assimilation activities will use both the CIMSS Regional Assimilation System (CRAS) and the NCEP Eta model. In a research mode, the CRAS will use sounder products of total and multi-layer moisture retrievals and cloud-top pressures to evaluate impact; forecast experiments with parallel runs of GOES-8 and -9 plus raobs (control) and GOES-8 and -9 only (experiment) will be run daily. In collaboration with NCEP, the 3-layer moisture retrieval impact on the Eta model (coordinating with Steve Lord) will be evaluated using GOES-9 retrievals over the Pacific basin starting March 1996. GOES-8 cloud information will be used to initialize the Eta model cloud fields (with Geoff DiMego of NCEP). CIMSS will also assist NCEP will efforts at direct radiance assimilation in the summer of 1996.

1997

Also investigation will be undertaken into the GOES-8 ability to depict boundary layer properties that may be influencing the development of convective activity. Techniques will be developed utilizing the shortwave channels on GOES-8 to provide improved surface skin temperature and lower layer moisture determinations. The net flux divergence and the inferred cooling rate will be determined on the mesoscale; these can be used to describe the radiative processes over terrain inhomogeneities surrounding atmospheric instabilities. As techniques show promise, the Techniques Development Unit at the NSSFC and the NWS MAR sites will be included in the evaluation through pilot demonstration programs.

later years

In the following years, comparisons with the past satellite capabilities and other current systems will be performed to assess the relative usefulness of the new data and the improved capabilities with the new instrumentation. At this time, day-2 algorithms and products will be defined. Throughout this activity, close collaboration with NCEP will be maintained and further data impact studies with NWS numerical forecasts will be conducted. This work will be conducted primarily by the CIMSS, in collaboration with the CIRA, the NESDIS Sounding Implementation Branch, and the NMC Development Division

3.2.5. Winds

WV winds

Currently, operational winds are derived four times daily from imager data, from a sequence of 3 half hourly images. The winds are calculated by a three-step objective procedure that are also applied to GOES-8 images with minor modifications. The initial step selects targets, the second step assigns pressure altitude, and the third step derives motion. An initial altitude is assigned based on a temperature/pressure derived from radiative transfer calculations in the environment of the target. That assignment is determined by using a pressure-temperature profile obtained from NMC forecasts, time and space interpolated to the location of the target. An initial guess motion is used, based on NMC wind forecasts at the estimated cloud level. The cloud motion is derived by a pattern recognition algorithm that locates a "target area" in one image within a "search area" in the second image. For each target two winds are produced representing the motion from the first to the second, and from the second to the third image. The first guess motion, the consistency of the two winds, the precision of the cloud height assignment, and the pattern recognition feedback are all used to assign a quality flag to the "vector" (which is

actually two vectors). The horizontal density of the vectors is controlled by the target selector. Initial height assignments are made using the CO2 slicing technique (with GOES-8 this is replaced by a H2O intercept method). These initial height assignments are quality controlled and some are adjusted by an autoeditor. This objective quality control attempts to minimize a penalty function where the cloud tracer temperature, height and velocity are compared with ancillary data (e.g. the 6 hour model forecast and aircraft wind reports). A quality flag is also assigned to the vector at this stage.

WV winds

Winds from moisture imagery (6.7 um, 7.2 um) are derived by the same methods used with cloud drift imagery. However, the images are separated by a full hour rather than a half hour. Heights are assigned from the water vapor brightness temperature. An attempt is currently made to exclude cloud targets from the target data set. However, research at EUMETSAT indicates that this may not be desirable, and the question will be addressed during the evaluation. Initial results of tracking WV features in the GOES-8 images has been very encouraging; impact tests on NMC models are planned for 1996.

deep layer mean flow

Combined cloud drift, moisture drift, and thermal gradient winds have been studied by the Atlantic Oceanographic and Meteorological Laboratory and the National Hurricane Center in the context better depiction of hurricane trajectories. CIMSS has coordinated production of these deep layer mean wind fields for the past ten years and participated with AOML in validation through aircraft dropwindsondes and evaluation in model impact studies. The deep layer mean wind field has shown considerable promise and is a day-1 product.

winds product assurance

Wind product assurance focuses on several activities. The accuracies of satellite winds are limited by the accuracies of the instrument calibration and earth location. Therefore quantitative post-launch measurements of those accuracies are being made available to the product validators. These include: image to image landmark (LM) motions, within-image LM to LM distances, earth edge measurements (IR), comparisons of window channel temperatures with known SST's and cloud top temperatures. Validation includes comparisons of satellite derived wind vectors with profiler, Doppler radar, aircraft, radiosonde wind determinations and ground sky camera stereo estimates of cloud motion. These efforts are being undertaken at CIRA and CIMSS (with some assistance from the University of Chicago in 1996). Impact of satellite winds on numerical models continues to be tested by periodic parallel runs of the model with and without the satellite motion information. Initial impact evaluation by NCEP (in July 1995) was non-negative and helped to declare the GOES-8 winds operational.

operational winds

In 1995 the operational day-1 winds product was established; this was accomplished through collaboration of CIMSS, the Sounding Implementation Branch, and the Product Systems Branch. The automated cloud motion vector software has yielded significant improvements in the quality of the GOES cloud-drift winds produced operationally by NESDIS. Cloud motion vectors resulting from the automated system are now equal or superior in quality to those which had the benefit of manual quality control a few years ago. The single most important factor in this improvement has been the upgraded auto-editor. Improved tracer selection procedures eliminate targets in difficult regions and allow a higher target density and therefore enhanced coverage in areas of interest. The incorporation of the H2O-intercept height assignment method allows an adequate representation of the heights of semi-transparent clouds in the absence of a CO2-absorption channel. Finally, GOES-8 water-vapor motion winds resulting from the automated system are superior to any done previously by NESDIS and should now be considered as an operational product.

early validation

Validation is proceeding with direct comparisons of collocated computed cloud motions and radiosonde observations. It reveals GOES-8 cloud motion winds to be within 6.5 to 7 m/s with respect to raobs, with a slow bias of about .5 m/s. Water vapor motions are within 7 to 7.5 m/s.

Evolution of the wind products requires review of the wind tracking process. Historically, problems (e.g. apparent slow bias in upper level satellite-derived winds) impede successful use of the data in forecasting operations. The recent Workshops on Wind Extraction from Operational Meteorological Satellite Data (Sep 1991; Dec 1993) suggested several new approaches, that include (1) further improvement in methods of height assignment for the wind vector including stereoscopic techniques (to augment the recent progress with the CO_2 slicing technique), (2) tracking features in more images with shorter time separations, (3) development of tracking techniques with visible imagery, complemented by both short and long wavelength infrared imagery, (4) improved integration with other data sources (e.g. numerical forecasts and profiler observations), and (5) tracking features in the retrieval fields rather than the radiance observations. This is an ongoing activity largely centered at the two NOAA cooperative institutes, CIMSS and CIRA, working closely with NMC. The Winds POP coordinates activities in this area.

3.2.6. Precipitation

The GOES I-M era offers exciting possibilities for the development and implementation of improved precipitation products. The present Interactive Flash Flood Analyzer (IFFA) is being converted to the new Interactive Data Utilization Center (IDUC), which allows the implementation of an automatic precipitation estimation technique. Three product areas are discussed below; IFFA, precipitation histograms, and moisture bogus. The activities outlined in this section are being performed largely by the NESDIS Physical Sciences Branch and are coordinated with the Precipitation POP.

IFFA precipitation validation involves comparison with ground-based observations. Because of the mesoscale nature of heavy convection and the sparsity of the raingauge network, it is difficult to get good verification of satellite rainfall techniques. Nevertheless, baseline statistics of IFFA accuracy are currently being developed from NMC 24 hour data bases. Plans are underway to access 3- and 6- hourly rainfall amounts to refine and examine the quantitative IFFA amounts. Pre-launch validation includes recoding the IFFA software for GVAR data; this needs to be tested periodically for operability with each McIDAS upgrade. Additionally, a standard must be developed for comparison of GOES-8 precipitation estimates. DMSP/SSMI precipitation algorithms, Meteosat VIS and IR, NOAA VIS and IR, and WSR88D are being used. Diurnal affects on IR data and resultant estimates are under evaluation. Errors associated with navigation, parallax corrections, and remapping are being characterized and mitigated.

Product evaluation includes inspection of all available parallel data sets listed above. Higher IR resolution requires fine tuning of decision tree coefficients/factors. Tropical, continental, and warm top convective systems must be evaluated for a least one year to assure IFFA estimates are equal or better than current accuracy levels. Selected NWS offices are evaluating the IFFA precipitation on a local scale; mesoscale observations and WSR88D data are being made available for validation. The WSFO at Milwaukee/Sullivan is one of several offices nationwide that is participating in a quantitative precipitation forecast risk reduction exercise; their evaluation of IFFA estimates is supporting both risk reduction activities and GOES I-M product assurance.

Day-2 product development is moving toward automation. The IFFA remains a manually intensive product to generate. Only one or two areas of the US can be monitored at any time. The Convective Stratiform Technique (CST), an automated precipitation estimation program, has been developed and tested. This would serve as a first guess to monitor all convective systems over the US. It also allows NESDIS to satisfy NMC requests for hourly estimates for the MAR mesoscale models. CST has been converted to McIDAS format. GVAR data operability has been established. Currently VDUC processing restraints prohibit operational parallel testing. Implementation of CST is improving the heavy precipitation "watch" and target

selection, particularly with the higher resolution IR data. A blended microwave, IR, and visible (tri-spectral) product is considered the best approach and is under development. NMC mesoscale model impact tests will be needed.

Validation of the precipitation histogram involves similar activities as baseline IFFA estimates, but navigation and parallax issues are of little concern to this product. Post-launch evaluation must include assuring IR calibration and cloud top temperature accuracy. Likewise diurnal and annual variability of sensor data must be established for product corrections. This is a climate product thus long-term consistency is vital.

moisture bogus

Moisture bogus techniques are nearly 20 years old and need major revamping. Utilization of moisture estimates is minimal by the NMC even though this information is of great interest to NMC. New approaches are currently being examined ranging from the Japanese Meteorological Agency approach that uses pattern recognition and 50 or so classes to a blended geostationary and polar product. Currently this is a manually intensive and very subjective technique that relies on a analyst to determine the cloud type and meteorological situation after which a moisture bogus category is assigned. Prelaunch validation will focus on developing a new analytical technique. One based on IR and water vapor data is being explored. Since the current technique relies only on imagery at reduced resolution, the accuracy of IR temperatures and navigation are of less concern than with other products. Post-launch evaluation must involve NMC model impact studies.

3.2.7. Surface Products

sfc

There are currently no day-1 surface products from GOES-8. However, research with the GOES-8 sea surface temperature has indicated that merging of polar and geostationary products is desirable. The polar offers high spatial resolution while the geostationary offers high temporal resolution (many looks per day help alleviate the influence of persistent clouds). CIMSS and the Physics Branch are working on this merged leo-geo product. Further, based on knowledge acquired from AVHRR and experiments with GOES-7 there are a number of other potential day-2 products. Among those products are insolation and clear sky land surface temperature. These are the responsibility of the NESDIS Land Sciences Branch and are coordinated with the Surface Products Oversight Panel.

3.2.8. Ocean Products

ocean

There are currently no day-1 ocean products from GOES-8. However, based on knowledge acquired from AVHRR and experiments with GOES-7 there are a number of potential day-2 products, specifically sea surface temperature. The inflight imager calibration accuracy, stability, and line-to-line, channel-to-channel, and scene-to-scene variations will have to be evaluated to decide whether imager performance is sufficient for SST calculation. If the performance is acceptable, a cloud-filtered temporal composite SST product for the U. S. coastal areas would be an asset to the Coast Watch part of the Coastal Ocean Program. A development effort spanning three years would be necessary to bring an operational product on line. Development of these products would be the responsibility of the NESDIS Physical Sciences, Marine Applications, and Ocean Sciences Branches. Their activities will be coordinated with the Ocean Products Oversight Panel.

3.2.9. Earth Radiation Budget

ERB

There are currently no day-1 earth radiation budget products from GOES-8. However, based on knowledge acquired from HIRS, AVHRR, ERBS, and experiments with GOES-7 there are a number of potential day-2 products. Potential activities include investigations of climate phenomena with large diurnal variations and the continued development of global products of the

International Satellite Cloud Climatology Project. The NESDIS Atmospheric Sciences Branch participates in ISCCP; activities in this area will be coordinated with the Earth Radiation Budget Products Oversight Panel.

3.2.10   Ozone

ozone

There are currently no day-1 ozone products from GOES-8. However, GOES-8 sounder has an ozone sensitive channel at 9.6 um. Development of future products in this area is the responsibility of the NESDIS Physics Branch; activities will be coordinated with the Ozone Products Oversight Panel.

3.3   Practical Implications of New GOES Observing Capabilities

3.3.1.   Imager

high quality imagery

* Higher quality imagery is acquired more frequently. Improved spatial resolution with better signal to noise of GOES-8 imagery combined with routine 15 minute views of the United States allows GOES-8 to provide better coverage for value added users such as TV meteorologists: weather animation (movies) seen by most Americans during the evening newscasts should be greatly improved.

combining with WSR88D

* Synchronization with other observations is better. Separate imager and sounder allow for more flexible scan modes. We are currently engaged in a Lake Effect Snow Experiment to help determine how to best utilize satellite and Doppler radar to enhance winter storm forecasting and nowcasting using 5 channel imager data and sounder products. The anticipated success of this program will provide improved weather services for Great Lakes shipping and heavy snow forecast for this important sector of our country. RAMSDIS units are in place at several forecast sites for this exercise.

better winds

* Cloud drift and water vapor winds are improved. The best water vapor (6.7 um) imagery ever (order of magnitude improvement enables identification of small scale disturbances within larger scale features). Improved winds will allow better hurricane motion predictions, more accurate numerical model forecasts (this has major impact in all areas of our economy and quality of life), and better winds for aircraft route planning. With the water vapor imagery, we can even see mountain waves in areas where clouds are not forming - this should improve turbulence forecasts for aviation.

fog at night

* Detection of fog is enhanced. During the day, combined visible and 3.9 um imagery will lead to improved fog detection (fog over snow). At night, fog detection is possible through a combination of the infrared bands; this is important for aviation purposes (Federal Express and similar enterprises have numerous nighttime routes) and marine activities (there is a major Marine Risk Reduction activity underway at Boston where we have a RAMSDIS and this product). Continuous monitoring from geostationary view complements polar orbiting determinations of fog.

SST

* Surface temperature monitoring is improved. Continuous monitoring of the surface (both land and sea) from geostationary view allows maximum opportunity of cloud free skies so that polar orbiting determinations are enhanced. This is important for shipping since SST gradients are related to currents. Enhanced land surface temperature monitoring is possible with the improved infrared bands and is important for agricultural applications such as early frost warning.

low-level moisture

* Depiction of changes in atmospheric moisture and stability is more timely and improved. There is no other sensor that can monitor low level moisture gradients as well as this satellite. This is very important for severe storm (tornado) forecasting: heat and moisture are the fuel for intense thunderstorms.

ice vs water clouds

* Capability now exists to distinguish ice and water clouds during the daytime, and to detect low cloud and fog versus snow cover. Using the visible, 3.9 micron and infrared window bands GOES-8 can distinguish between ice, water and super-cooled clouds: aircraft icing is a super-cooled cloud phenomena and is extremely hazardous to small aircraft.

low light imaging

* Low light imaging is possible with 10 bit visible data. Extended utilization of one km imagery allows better location of atmospheric events such as fog, haze and pollution, and intense thunderstorms.

fire detection

* Detection of forest fires and biomass burning is improved. Assistance with fire weather activities are possible. There are RAMSDIS units at Seattle, Salt Lake City and Boise that we hope to test these products with next summer. GOES-8 can see 20 to 50 acre fires in remote areas before they are detected from the ground.

tracking sea ice

* Polar viewing capability is greatly enhanced. Imagery is now useful well beyond the previous north/south limits. GOES-8 sees clearly up to the Arctic (or Antarctic) circles for improved tracking of sea ice and monitoring of ice and snow cover. This area is an important one for combined polar and geostationary products.

one minute imaging

* Depiction of atmospheric changes is best ever in one-minute interval imaging. Work is currently underway to determine optimum ways of combining WSR88D radar and satellite rapid scan data. With one minute interval imagery over Hurricane Rosa, we were able to track low level clouds at 70 knots near the hurricane eye. Rosa was estimated to have a 75 knot maximum wind speed.

3.3.2   Sounder

moisture for models

* First operational geostationary sounder is providing full time coverage (no untimely gaps). Much better radiometric performance (signal to noise better by factors of 5 to 10) especially in the water sensitive bands will provide positive forecast model impact. GOES-8 will yield greatly enhanced depiction of changes in atmospheric moisture and hence atmospheric stability from soundings. Improved weather forecasting will have major impact in all areas of our economy and quality of life.

ASOS cloud support

* Hourly supplement to ASOS is continued. Accurate delineation of clouds above 12,000 feet is very important to aviation and weather outlooks.

boundary layer thermodynamics

* Depiction of boundary layer thermodynamics is better. Using the shortwave bands on the sounder, we expect to improve low atmospheric temperature and moisture determinations which are critical for improved severe weather watch box determination.

thermal winds for hurricane trajectories

* Quality of thermal gradient winds is higher. This means that improved hurricane trajectory forecasts from cloud motion, moisture drift, and thermal gradient winds are possible. Better definition of landfall has huge financial implications for inhabitants on the east coast and the Gulf of Mexico.

PW

* Moisture determinations for precipitable water monitoring is improved. This capability should allow us to better isolate areas where very heavy rains are likely.

ozone monitoring

* First ever continuous monitoring of ozone is possible. We can watch for diurnal, seasonal, and annual changes in total ozone content in the atmosphere over the northern hemisphere. Implications for ozone alerts will be explored.

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4. INTEGRATION OF EVALUATION/VALIDATION RESULTS INTO OPERATIONS

4.1. Role of the POPs

Product Oversight Panels (POPs) play a key role in the pre- and post-launch activities. They have representatives from the user communities, and can be enlarged to include "consultants" or representatives to ensure all interests are covered. Since POPs are co-chaired by operations and research, they are the conduit for identifying problems, testing out proposed solutions, and bringing the improvement on line. Identifying problems appears to be aptly handled through user participation at the POPs: the users are on the forefront and can inform NESDIS promptly of problems. Monthly reporting to the GOES Program Manager assures that management is informed of progress within each POP. Testing improvements and implementing them in a timely fashion remains the biggest challenge to the POPs; computer and people resources must be identified and allocated. It is the responsibility of the individual POP co-chairs to identify those necessary resources. Additionally, a strong management commitment to ensure highest priority is prerequisite. Current co-chairs of the ten different POPs are indicated in Appendix B.

POPs manage

4.2. Role of the SPRB

POPs report to the Satellite Products Review Board (SPRB) every month. The SPRB reviews user acceptance of products and progress on new product implementation; technical and resource problems are presented and solutions are suggested whenever possible. All new products must receive favorable review by the SPRB before they can become operational.

SPRB reviews

4.3. Role of the TAC

The Technical Advisory Committee (TAC) is an advisory body that is composed of representatives from agencies using and developing GOES data products. The TAC provides a mechanism for community-wide coordination of GOES product research and development. The TAC is responsible for (1) setting priorities for GOES product research and development, (2) providing technical guidance on feasibility and difficulty of new GOES product efforts, and (3) soliciting technical advice from outside the GOES community when necessary. They work with the GOES Program Manager to guide product development and to prioritize resource allocation. Outside users can route new product requests through the TAC. NESDIS chairs the committee which has representatives from NESDIS, SAO, NWS, ERL, NASA, DOD, FAA, and the university community (see Appendix B for list of current members); normally, two meetings a year are held. The idea is borrowed from the WSR88D program, which has been served well by their TAC.

TAC advises

4.4. NWS participation

The user evaluation within the NWS is coordinated at each of the National Centers, NWS MAR sites, and selected field offices. As techniques show promise, Science Operations Officers (SOO) at appropriate NWS locations are included in the evaluation through pilot demonstration programs. People at these locations have access to digital GOES data and products and are responsible for providing feedback on product timeliness and utility. Strong interaction through RAMSDIS is occurring and is expected with AWIPS. Algorithms will be adjusted based on NWS recommendations to the POPs and the SPRB.

NWS SOOs

4.4.1. NSSFC (SPC and Aviation Weather Center)

The GOES-8 is significantly enhancing the utility of satellite data in severe weather forecasting beyond GOES-7. The improved 10 bit visible digitization shows much greater details of cloud features as does the improved 4 km resolution of the infrared imagery. The 4 um channel enables forecasters to see small clouds near the ground at night as well as distinguish ice clouds from water clouds. The split window allows monitoring of low level moisture. The independent operation of the sounder produces more timely and higher quality soundings and derived product images (e.g. total precipitable water and lifted index). Forecasters of the Techniques Development Unit at NSSFC are working with scientists from NESDIS, CIMSS, and CIRA to explore these new opportunities.

4.4.2. NHC (TPC)

The NHC uses both the imagery and the derived winds provided by the GOES system. High density cloud drift winds (and water vapor drift) are produced from imager movie loops. Thermal gradient winds in the subtropics produced with the sounder have recently been found to be providing good information on atmospheric motion in non cloudy skies. The combination of the imager and sounder winds is used to infer mean atmospheric motions associated with tropical cyclones and their steering currents. NHC forecasters continue to work with NESDIS, NMC, AOML, CIRA, and CIMSS scientists to utilize the improved GOES-8/9 imagery and to evaluate the impact of the new wind sets on their forecast procedures and their model initializations.

4.4.3. NMC (NCEP)

An extensive effort is underway at NCEP to develop the Regional Data Assimilation System (RDAS), which is capable of accepting data on frequent (e.g. 3 hourly) cycles for both level and layer parameters. Thus NCEP plans to be in position to exploit the spatial and temporal information available from the GOES-8/9 products (e.g. cloud-tracked winds, temperature retrievals, layer moisture retrievals, cloud top temperatures). Cloud-tracked winds from short interval (e.g. 15 minutes) imagery in regions where other observations are sparse will receive increasing attention; however the upper level slow bias must be understood and accounted for. Temperature retrievals will be valuable especially over oceanic regions, but they must be competitive with those from the TOVS (within 2.5 C rms of radiosondes). Layer moisture retrievals, hopefully improved by the additional moisture channels on GOES-8/9, should provide a good bound on several moisture layers for a large area of the western hemisphere. Cloud top temperatures and effective cloud amount should indicate cloud type and location. Additionally products such as snow and ice cover, surface temperature, and water vapor tracked winds will provide information that cannot be provided by other sensors. All parameters, as well as thermal gradients expressed as gradient winds, will also be used by the Global Data Assimilation System (GDAS), but on a 6-hour cycle.

Impact of a given GOES product will be measured by the Development Division of NCEP in a series of tests where the RDAS (and/or GDAS) is run with and without the GOES information. Close coordination with assimilation efforts at FSL, CIMSS, and CIRA will be required. These tests will be scheduled with the appropriate Product Oversight Panel (POP) and will typically run ten to twenty days. Feedback from these tests will be funneled through the POPs and appropriate product availability will be arranged or the desired product adjustment pursued.

In the July 1995, ETA model impact studies were conducted with three layers of moisture determined from the GOES-8 sounder every three hours over CONUS. Soundings used the ETA forecast as a first guess, soundings were processed from 5 by 5 fields of view, and observed sounding radiance bias corrections were calculated from previous comparisons with the

(margin notes:)

derived product images
for TDU

WV winds for NHC

model impact studies
with NCEP

ETA forecasts. The retrievals of 40 levels of temperature and 21 levels of dew point temperature were converted into three layers of moisture by NMC, who ran the 80 km ETA model parallel with and without GOES-8 sounder data. Modest but persistent positive impact was found in the precipitation threat scores. Given that these tests were run over the data rich CONUS, it is now planned to conduct similar tests with GOES-9 over the data sparse Pacific in the fist and second quarters of 1996.

NCEP tested atmospheric motion depicted by cloud motion vectors tracked in GOES-8 images in their global model every six hours. Parallel runs with GOES cloud motion and without showed little difference. The non-negative impact encouraged NCEP to ask for operational production of the GOES-8/9 winds, with the anticipation that further study and assimilation efforts would yield the expected positive impacts. Special cloud and water vapor wind sets from the 1995 hurricane season are being studied by NCEP to evaluate the impact of higher density wind data sets.

4.4.4. FSL

The Forecast Systems Laboratory (FSL) supports this plan through several activities: (1) evaluate data quality over ISPAN through interaction with the forecast office and the NWS; (2) test various remapping algorithms to assure equivalent product quality from GOES-8/9; (3) work with CIRA in comparing analysis strategies with those developed for GOES-7; and (4) check GOES-8/9 data using LAPS (Local Area Prediction System) surface temperature, cloud, and moisture analyses. FSL has been working with GOES data for the past 10 years in a number of areas. They include the testing and refinement of algorithms (e.g., split-window VAS moisture product, GOES soundings and derived image products), participation in the VAS assessment, and collaboration with CIRA in improving satellite products targeted for AWIPS. FSL is continuing this interaction. In addition, FSL is working with the (NWS Denver) operational forecast office to test new satellite products and applications and refine existing ones. In the late-1990's, ERL is moving into a new building that also houses the NWS Denver forecast office. FSL will occupy offices next to the weather service allowing direct interaction between operational forecasters and FSL researchers and algorithm developers.

The major vehicle to get satellite data to the future operational offices is through GINI processed data distributed through NOAA-PORT. FSL receives ISPAN distribution now and plans to test the data by using it as input in both analysis and product generation. Additionally, FSL has a GVAR ground station. With both ISPAN and direct received GOES-8/9 data, as a day-2 activity FSL is determining improvements to the ISPAN data feed and assess its value compared with data from GOES-I GVAR ingest. FSL has "operational" experience using GOES-7 data in the local analysis and prediction system (LAPS) and meteorological display algorithms. Further, depending on the impact of the activities mentioned above, FSL can perform satellite data impact experiments by comparing forecast model output based on initialization made with and without satellite data.

4.4.5 NSSL

The National Severe Storms Laboratory is participating in GOES training and studying the best ways to amalgamate GOES-8 and WSR88D data. Several case studies are being pursued to combine WSR88D depictions of rainfall echoes with very rapid interval imaging from the GOES-8 imager; the VORTEX (Verifications of the Origins of Rotation in Tornadoes Experiment) experiment conducted in April to June 1995 produced several case study data sets. A RAMSDIS unit was placed at NSSL to support VORTEX and scientists from CIRA and CIMSS participated

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on site in that experiment. Additionally scientists from NSSL are spending extended periods of time at both cooperative institutes.

4.4.6   NWS Field Offices

user feedback

During the first years of GOES-8/9, CIRA is coordinating evaluation activities with the NESDIS Satellite Services Division at selected GOES-TAP sites receiving GOES-8/9 data through the NESDIS/NWS "No-GOES" contingency facilities and those sites receiving imagery from GINI. Candidate sites include field offices with a SOO and field offices with internet capability.

RAMSDIS

Additionally some fifty plus sites that acquire digital GOES data their RAMSDIS (Regional and Mesoscale Meteorology Branch Advanced Meteorological Satellite Demonstration Interpretation System) via internet access. CIRA is customizing the display menu on RAMSDIS for individual sites, maintaining the units in the field, and orchestrating training exercises using them.

Milwaukee/Sullivan
Cheyenne

CIMSS is working with the nearby Milwaukee/Sullivan WSFO in the evaluation of the new satellite data and the derived products. This takes advantage of the local availability of WSR88D, ASOS, and Profiler data as well as bringing together operations and development personnel to plan further product enhancements. CIRA also has a similar close working relationship with the Cheyenne WSFO.

4.4.7.   National Centers for Environmental Prediction

reorganization of NMC

The NMC has been restructured to include operational climate and ocean prediction as well as short range weather prediction. The successor organization is called the National Center for Environmental Prediction (NCEP) and consists of six national centers that generate environmental prediction products and two centers that perform the modeling activities on which the predictions are based. The centers are Storm Prediction Center (SPC), Hydrometeorological Prediction Center, Aviation Weather Center, Tropical Prediction Center (also NHC), Marine Prediction Center, Climate Prediction Center, Environmental Modeling Center (EMC), and the NCEP Central Operations. Active GOES-8/9 evaluation and utilization projects are already in place with EMC (impact studies of sounder moisture products and imager winds on regional and global forecast models), SPC (nowcasting studies of derived product images of total precipitable water vapor, atmospheric stability, and cloud top pressures); and NHC (hurricane trajectory forecasts using water vapor and thermal gradient winds); other centers are being approached to participate in the GIMPAP as appropriate.

4.4.8.   Informing the User Community

active training program

GOES information and training is required for the broad user community. This is the responsibility of NWS and NESDIS, as well as CIRA and CIMSS. With the launch of GOES-8/9, selected technical memoranda have been updated for the user community. These are summarized in Appendix F, as well as other NWS and NESDIS plans for providing information to the user community. An active user training program coordinated within NOAA was a fundamental part of the WSR88D integration into the NWS. Appendix H outlines the training plan for integrating GOES-8/9 into the NWS and facilitating broader use of the GOES data; it has been coordinated between NWS and NESDIS uses COMET extensively and is included in our cost plan of Appendix A.

5.   EVOLUTION TO IMPROVED PRODUCTS

While much of the initial focus for product validation is on GOES-8/9, the important issues of changes to the GOES I-M series and the future beyond GOES-M should be addressed also. Two science teams have been organized to this end: the GOES Imager Science Team headed by Dr. Jim Purdom and the GOES Sounder Science Team headed by Dr. Paul Menzel. These teams meet periodically to evaluate possible modifications to existing instruments and planning of future instruments. Their recommendations are reviewed by the GOES Council and forwarded to the Systems Acquisition Office for action. This section presents some of the present thinking on evolution of products and instruments.

5.1.   Evolution of Products

day-2 possibilities

Products will evolve as experience is gained with the new GOES spacecraft configuration and its improved capabilities. In Appendix G, operational schedules for the east and west GOES are indicated. These schedules enable development of new products and assessment of their usefulness to the NWS and other users. The day-1 products have been listed in Appendix C. Possibilities for day-2 products include mesoscale winds from very rapid image intervals, cloud products like fog and cloud emissivity from the imager, gridded cloud information from the sounder, automated precipitation estimates from the imager and the sounder, sea surface temperature from the imager, ozone from the sounder, and land surface or radiation budget flux values from the sounder.

procedure for introducing day-2

The exact process of evolving from day-1 to day-2 products will rely on scientific research, a demonstration program for the NWS, coordination with the appropriate POP, approval by the SPRB, and implementation by the Office of Satellite Data Processing and Distribution (OSDPD). This plan requests funding for this procedure. This process will be enhanced if a working group is established which meets periodically to discuss and encourage product developments.

5.2.   Establishing a Working Group

GOES working group

Since 1983 the International TOVS Working Group has been studying the quality and applicability of satellite derived temperature and moisture profiles for operational purposes. The meetings of this group have proven to be a successful venue for exchange of information and algorithms. More recently in 1991, an initial meeting of the International Winds Working Group convened the international producers of satellite derived atmospheric motions to share information on cloud and water vapor drift winds and the associated height assignments. There is a need for a GOES Working Group that functions in much the same way.

Such a group would start with the community having GOES/VAS or NOAA/TOVS experience and expand to include new GOES I-M users. International participation would be encouraged. Working group meetings would provide a venue for geostationary experts to discuss progress and goals, as well as a sounding board for new products and instruments. It would facilitate validating day-1 products, getting day-2 products tested and made operational sooner, and evolving the GOES instruments for future needs.

5.3   Participation in Field Experiments

As mentioned in section 2.3, the evolution of products will depend on experience with day-1 products, scientific development through case studies, and participation in field experiments. Interaction with other NOAA components, particularly NWS and OAR, as well as the broad science community is helping with this endeavor. RAMSDIS, although not thought of in terms of a field experiment, is such an experiment in the broadest sense. NWS field offices are able to

routinely view and analyze digital multi-spectral imagery and derived product imagery from GOES-8/9 using that system. Those units are able to derive a number of simple products from digital GOES imagery and assess its utility for field operations and applicability future AWIPS products. Examples of such products include nighttime fog and stratus imagery, time of arrival of a forecast feature, determination of cloud top temperatures, and loops composed of averages of current images. These investigations include Alaska where the utility of geostationary imagery at 15 minute intervals near the earth's limb will be investigated. A formal mentor program and feedback mechanism exists within the RAMSDIS experiment that allows for assessment and evolution of day-1 products and testing of day-2 products.

Other field experiments have occurred or are planned for GOES product evolution. Those experiments include massive collections of special sounding fields along with one and three minute interval imagery for investigation of a large variety of phenomena of interest to the NWS. These include: general and severe convective storms; tornadic storms; tropical storms and land falling hurricanes; winter storms, with concentration on Great Lakes snow systems. Many of those special satellite data sets have been collected in conjunction with data from the WSR88D radar and other special observational platforms. Two experiments whose data are currently under intensive investigation are VORTEX, which focused on tornadic storm formation and evolution, and Great Lakes Winter Storm, which is focusing on nowcasting winter snows in the Great lakes using WSR88D and GOES satellite data. Further, a large number of hurricanes and tropical storms were observed with one to 15 minute interval satellite imagery while they were being observed with NOAA hurricane hunter aircraft. To aid in the diagnosis of satellite imagery taken during those experiments, special RAMSDIS units have been placed at NSSL and HRD, where research is underway on common cases with resident scientists and CIRA scientists. Research RAMSDIS units will be loaded with one and three minute imagery and placed in appropriate NWS field units (with initial focus on the Great Lakes) that will work with that imagery, in consultation with CIRA scientists, to ascertain the benefits of more frequent satellite imagery for nowcasting.

Plans call for continued active involvement with the broad science community to further the use of advanced GOES imagery in field experiments. The Great Lakes Experiment is expected to continue during the winter season of 1996/1997. Special support is being given to the Olympics forecast center where rapid scan satellite imagery will be used to help formulate 15 minute interval nowcasts during the 1996 summer games in Atlanta; similar support is planned for the upcoming winter games in Utah. During the winter of 1997, an international field campaign to study Atlantic Ocean storms, called Fronts and Atlantic Storm Tracks Experiment (FASTEX) will take place. Special satellite data sets will be acquired as a part of this experiment for joint study with scientists from NOAA/ERL, Canada and the United Kingdom. RAMSDIS, with specially designed GOES-8/9 products, is expected to play a key role in that experiment by being located in either the forecast support office in Shannon, Ireland, or the University of Reading support facility located in Reading, England.

Experience from the above mentioned experiments has provided, and is expected to continue to provide, a wealth of information which allows for development of meaningful day-2 products. Also, experience gained in the use of advanced satellite data sets to support field experiments should prove invaluable in the planning and support of field efforts of the future, including those associated with the US Weather Research program.

5.4   Day-2 Products

There are a number of day-1 enhancements and day-2 product development areas that are being explored primarily at the cooperative institutes and SAL. The following table indicates some of

the products currently being advanced. It should be noted that by the end of this century, the new NOAA observing system will be in place. This will include WSR88D weather radars, wind profilers, automated surface observing stations (ASOS), and winds and temperatures along commercial aircraft routes (ACARS). Observational data, such as GOES, will be automatically displayed on the Advanced Weather Interactive Processing System (AWIPS). New products will need to be developed which rely on information from the partnership of new high technologies that will accompany NWS modernization.

Table: Day-2 Products

Image, Clouds, and Aerosol

fog, smoke, ash	*	Detection and monitoring of smoke, pollution, volcanic ash and blowing dust.
cloud phase	*	Cloud type and cloud top phase both day and night; including nighttime fog and stratus using 3.9 micron "reflected solar" product for identification of water cloud, ice cloud and snow as well as cloud over snow and ice.
principal component analysis	*	Imager principal component imagery used to locate regions of blowing dust, low level moisture, surface thermal gradients under clear skies as well as more conventional multi-channel products such as fog, cirrus and snow cover.
GOES and WSR88D combined	*	Severe storm nowcasting techniques from combined satellite and WSR88D data, eventually blended with storm scale models for objective assessment and short term prediction. Phase one would include a time evolution of overshooting thunderstorm tops and anvil characteristics to assess thunderstorm intensity.
mesoscale winds	*	Convective potential product which uses satellite mesoscale winds and thermodynamic information. This product will be used to augment information from other sensors, and will evolve into a combined modernization data product.
MCS lifecycle	*	Analysis of MCS lifecycle, and eventual nowcasting, from objective IR cloud top analysis along with radar, and eventually mesoscale models.
storm relative	*	Storm relative average imagery at various time scales, and as running mean loops, for cyclonic storm system analysis, characterization and forecasting.
IPV	*	Inferring potential for Isentropic Potential Vorticity intrusions into the troposphere and rapid cyclogenesis using of water vapor imagery and model data
tropical cyclone	*	Tropical cyclone characterization from a) objective digital IR analysis of current tropical cyclone intensity, with or without eye; b) refined surface wind field distribution using satellite cloud motions, IR intensity and microwave data from polar orbiters; c) objective IR based algorithm to detect (predict) rapid intensification; d) objective cyclone motion nowcast and 24 hour forecast algorithms based on storm intensity, past motion and water vapor winds.
clear air turbulence	*	Detection of regions of clear air turbulence in the lee of major mountain ranges using water vapor imagery.
low level jet	*	Low level jet development and evolution at night by combining Doppler radar radial wind information with surface cooling rates as detected using satellite IR data.

Table: Day-2 Products (continued)

Image, Clouds, and Aerosol

small cumulus

*   Daytime 3.9 micron IR product for improved warm/hot area temperature analysis, identification of small cumulus cloud and cloud free thermal boundaries.

vorticity centers

*   Model assessment by comparison with water vapor imagery motion and the location, diagnosis and tracking of vorticity centers using water vapor imagery.

Winds

high density auto winds

*   higher density winds with improved tracer selection

mesoscale winds

*   mesoscale winds from very rapid image intervals with cloud heights using time adjusted stereo - geo/geo or geo/polar. This includes, but is not limited to, local wind fields from combined satellite cloud motions and WSR88D radial winds as well as mesoscale low level cloud drift winds in the Coastal zone.

geometric cloud heights

*   Cloud heights from geometric techniques using shadows and stereographic observations (both geo/geo and geo/polar).

Soundings

grids and DPI

*   Gridded and imaged cloud information from the sounder

better cloud clearing

*   Refined cloud clearing using model forecasts of surface parameters.

T(p) and q(p)

*   Temperature and moisture soundings independent of a model first guess

principal component imagery

*   Sounder principal component imagery in various combinations to yield information about atmospheric instability, dynamics and cloud properties.

direct assimilation of rad

*   Assimilation of radiance data directly in forecast models

Precipitation

auto precip

*   Automated precipitation estimates from the imager

combined with WSR88D

*   Automated precipitation algorithms from combined satellite and WSR88D data which eventually blend with storm scale models for quantitative precipitation amounts and type.

better rain template

*   Better screening of rain/no rain events with shortwave longwave windows

Ocean

POES-GOES SST

*   Sea surface temperature from the GOES merged with AVHRR estimates

Surface

biomass burning

*   Automated detection of fire temperature and areal coverage with the Automated Biomass Burning Algorithm (ABBA).

Table: Day-2 Products (continued)

<u>Surface</u>

snow cover	*	Estimation of snow cover.
sfc albedo	*	Estimation of surface albedo
sfc analysis	*	Detailed surface analysis from rapid interval satellite imagery and advanced objective analysis techniques which rely on surface and radar data.
insolation	*	Insolation and albedo of clear sky CONUS

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6. Evolution of the GOES Instruments

6.1 Modifying the GOES-M Imager

At recent meetings of the GOES Council approved modification of the GOES-M imager to accommodate a CO_2 channel and to increase the spatial resolution of a broadened H_2O channel. This would be accomplished in the following way: substitute a 13.1 to 13.7 um channel for the present 6.5 to 7.0 um channel on the 8 km detector (channel 3) and increase the spectral range of the H_2O channel to 5.8 to 7.3 um and substitute it for the present 11.5 to 12.5 um channel on a 4 km detector (channel 5). The addition of the CO_2 band benefits the imager ASOS cloud product with improved height and amount determinations, and also allows cloud motion vector height assignments to revert back to the more accurate CO_2 slicing method used with GOES-VAS. The broader water vapor band with twice the present spatial resolution greatly enhances detection of detail in the atmospheric moisture variations lower in the atmosphere, improving nowcasting applications and water vapor wind determination for hurricane motion forecasting. Thus three NWS operational product areas benefit: satellite cloud information above 10,000 feet supplementing the ground based ASOS determinations of cloud cover used in the hourly roundups; improved height assignments for cloud motion vectors as well as improved moisture drift winds used in numerical weather prediction models; and improved measurement of moisture gradients for severe storm nowcasting and watch box delineation. NWS requirements dictate the need for these changes.

The R and D Council deemed that the loss of the 11.5 to 12.5 um channel is tolerable for the GOES-M spacecraft. It is often used in conjunction with the 10.2 to 11.2 um channel to estimate low level water vapor, to correct for atmospheric moisture attenuation in determining sea surface temperatures, and to estimate total precipitable water vapor. However, at present there is no operational GOES SST product and the low level water vapor product and estimates of total precipitable water are done by the sounder.

6.2. Evolving to GOES-NOPQ

Several studies are underway to determine the feasibility of enhancing imager performance with more spectral bands and faster scanning. These are guided by the Imager Science Team (chaired by Jim Purdom). More spectral bands (see the following table) may be accomplished with bi-color detectors. Faster scanning would require using redundant infrared detectors already in place and adding eight more visible detectors. So far indications are that these improvements are possible with modest changes to the GOES-8 imager.

Adding more spectral bands might slightly degrade the performance of some of the existing bands. However the benefit of imaging eight spectral bands rather than just five is large. The additional 1.6 um band allows better definition of ice versus water clouds, droplet size determination, as well as a low light viewing capability. The additional 13.3 um band allows cloud height and amount definition for cloud motion and ASOS support. The 5.1 um band helps to discriminate mid-level moisture and its motion for nowcasting and hurricane trajectory forecasting.

Adding visible detectors pushes the imager modifications into a more difficult terrain. Also, the ability to scan twice as fast raises the concern of data volume and communication bit rates. Several bit compaction schemes are under study; more needs to be done here to characterize the loss of detail versus the compaction achieved. Effect on GOES product must also be assessed (in collaboration with CIRA and CIMSS). However, the promise of alleviating some of the conflict between mesoscale and synoptic scale imaging requirements calls for further work in these areas. The following table indicates the planned spectral bands, their spatial resolution, noise equivalent temperature, and their primary usage.

Table: GOES-NOPQ Imager Spectral Bands, Resolution and Noise Characteristics, and Primary Usage.

Ch	Half Bandwidth (um)	Spatial Resolution (urad)	NEDT (deg C)	Range (deg K)	Use
1 to (stay below .72)	.52 +/- .01 .71 +/- .01	28 +/- 15%	3/1000	0 to 100%	cloud
2 to (stay below 4.15)	3.73 +/- .03 4.07 +/- .03	112 +/- 15%	0.2C at 300K	4-335K	cloud fire fog
3 to (stay centered at 13.3 +/- .05)	13.0 +/- .07 13.7 +/- .07	112 +/- 15%	0.7C at 300K	4-320K	cloud height
4 to	10.2 +/- .1 11.2 +/- .1	112 +/- 15%	0.20C at 300K	4-320K	Tcld winds Tsfc
5 to (broadened to accommodate 4 km FOV)	5.8 +/- .1 7.3 +/- .1	112 +/- 15%	0.30C at 230K	4-320K	water vapor winds UTH
6 to (keep 12.65 absorption within band)	11.5 +/- .1 12.75 +/- .07	112 +/- 15%	0.25C at 300K	4-320K	PWV SST
7 to (stay centered at 5.35 +/- .03)	5.2 +/- .03 5.5 +/- .03	112 +/- 15%	0.3C at 250K	4-320K	mid level H2O winds
8 to (detector limits bandpass to below 1.65)	1.5 +/- .01 1.65 +/- .01	112 +/- 15%	3/1000	0-100%	snow cld phase

Spectral bands for NOPQ imager

Continued pursuit of improved sounders was recognized as an important activity. The geostationary instruments enable observations at high temporal resolution, but the balance of temporal and spatial resolution has not been achieved with the present system. The most useful information comes when the aspect ratio of vertical to horizontal resolution is about 100 (e.g. about 1 km vertical is useful at 100 km horizontal). In the modernized NWS combined observing system, the GOES must have 1-2 km vertical resolution with 1 K accuracy (3 K accuracy for dewpoint) to contribute. Improved vertical resolution requires higher spectral resolution because this implies a need to resolve between absorption lines to see into troposphere. Indications are that an interferometer on GOES NOPQ gets us close (better than 2 km vertical resolution and 1 K accuracy). Plans for proceeding with this and with a parallel initiative for future GOES (new bus, new options) are in place. These efforts are being guided by the Sounder Science Team (chaired by Paul Menzel).

geo-interferometer studies guided by Sounder Science Team

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6.3.   Planning GOES-R

GOES-R is the designation given to the next generation of geosynchronous weather satellites after GOES I-Q. The first GOES-R will be needed when the existing GOES I-Q expire. In the past two years, there have been several meetings between NESDIS, SAO, NWS, NASA, and MIT Lincoln Lab to discuss options for evolving to the GOES-R satellite series. The philosophy was to design a satellite system that can operate in the 21st century recognizing that NOAA's products, services, and capabilities will undergo a continuous process where they are re-examined and re-shaped. The strategy for evolving to GOES-R focused on the following issues:

strategy for GOES-R

* we must assure a continuity of geostationary observing service,

* improvements to GOES I-Q must begin this decade,

* we must achieve a flexible geostationary system which
  can accommodate incremental improvements, and

* NOAA's satellite system and the rest of NOAA's modernized
  observing service must complement each other.

The current goals for the GOES-R system include

goals for GOES-R

* continuity weather services and compatibility with modernized components
  (nowcasting, forecasting, and climate using evolved imagers and sounders)

* all weather observing capability
  (emphasis on moisture and hydrology using a geo microwave 183 Ghz at least)

* geo-radar-like capability
  (improved severe weather monitoring and precipitation products using a lightning mapper)

* detecting ocean pigments and chlorophyll
  (coastal ocean stewardship with a geo-Seawifs for mapping atmospheric aerosols)

* improved solar monitoring
  (solar activity and particles using evolved SEM)

* search and rescue functions
  (location of distress signals with SAR)

* data collection and dissemination
  (enhancing DCP functions)

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The configuration for the GOES-R imager and its desired capabilities are nearly known. It is felt that about ten imaging channels are necessary; similarity to second generation Meteosat is desired. Those channels would probably include

10 channel imager
10 min full disk

vis	narrow band	high resolution day viewing
	broad band	
NIR	1.6 um	clouds over snow
IR	3.9 um	window
	6.7 um	upper trop moisture
	7.5 um	mid trop moisture
	8.6 um	clouds and phase
	10.7 um	window
	12 um	low trop moisture
	13.6 um	cloud heights

Desired resolution would be .5 km for the visible, 2 km for the near infrared, and 3 km in the infrared. Full disk imaging would be accomplished in about 10 minutes, and independent CONUS in 2.5 minutes or less. The noise equivalent temperatures would be about 0.1 C at nominal scene temperatures.

faster interferometer

The improved sounder would expand on the capabilities of the GOES-NOPQ sounder by adding active cooling and focal plane detector array technology. The goal would be to improve the signal to noise characteristics and to enable faster sounding coverage.

The present four initiatives involve

* Continue work as soon as possible on an improved sounder with high spectral resolution for the GOES I-M bus;

* Study and implement improvements to the GOES I-M imagers, such as 4 km resolution water vapor images and bi-color detectors to get extra spectral bands

four new initiatives

* Begin studies of a new imager with 10+ channels, time sharing, improved resolution, full disk in 10 minutes, and detector arrays;

* Begin studies of a new sounder with high spectral resolution, focal plane arrays, and active cooling.

The GOES applications for ocean and marine programs must be enhanced with these new instruments. The geostationary version of SeaWIFS mentioned above provides an ocean color capability. Practical applications include coastal water quality mapping, monitoring waste disposal at sea, oil spill detection and tracking. Research possibilities include observing phytoplankton sources and sinks on short time scales, characterizing productivity in the tropics, studying coastal upwelling areas, investigating local influences on pigment biomass such as plumes and eddies, understanding the timing of phytoplankton production on fisheries recruitment, tracking changing boundaries of water and land due to distribution of suspended sediments in river floods, and calibration of water leaving radiances from ocean gyres. The ocean research community has expressed a strong interest in enhancing the geostationary ocean observing capability.

enhance ocean
applications

guidance from the TAC

The Technical Advisory Committee will play a key role in defining the future GOES requirements and identifying possible robust satellite configurations to fulfill them. The next generation GOES should not be a high-risk step function, but should be continuous, well-tested, and incremental. For the future GOES program, continuity of coverage is a key necessity, but evolution to improved capability is another. Designers may look for innovative instruments to provide continued data coverage and improved data for advanced products.

APPENDIX A. Responsibility and Cost

Product assurance responsibilities and costs are outlined in this section. More detailed budgets will be expected in the individual proposals to the GOES Program Manager from the participating groups. Costs required to implement and maintain these products in the Office of Satellite Data Products and Distribution are not included.

A.1. Responsibility

	NOAA SAL/ SRL	SPC	TPC	NCEP	WSFO	FSL	AOML	Coop CIMSS	Inst CIRA	COMET
Images	X	X	X		X	X		X	X	
Clouds	X				X			X		
Soundings	X	X	X	X		X	X	X	X	
Winds	X		X	X			X	X	X	
Precip	X			X	X					
Other[a]	X			X						
Training	X				X			X	X	X

[a] This refers to the day-2 product activities in surface products, ocean products, earth radiation budget, and ozone.

A.2. Cost (in $1000 units)

FY	Total	NOAA SAL/ SRL	NCEP	NSSL	NWS	COMET	FSL	Coop CIMSS	Inst CIRA
1996	2600	748	60	30	250	250	139	605	518
1997	2600	755	90	60	250	250	146	595	454
1998	2650	830	90	70	250	250	150	565	445
1999	2650	850	120	70	250	250	140	545	425
2000	2700	880	120	70	250	200	130	595	455

Support for research at NASA and other facilities is being sought separately from NASA. AOML research proposals have been submitted to NOAA.

APPENDIX B. Management Plan for Each Product

The management of all GOES I-M Product Assurance activities is accomplished with a three tiered structure. Top leadership and overall responsibility resides with the "GOES Program Manager". In the second tier, an "ORA GOES Scientist" and an "OSDPD Product Coordinator" are responsible to him to assure work is done, milestones met, and implementation accomplished. Finally, in the third tier, the Product Oversight Panels (POP) see to the maintenance and evolution of the products. The POPs report on progress at the monthly SPRBs and other venues, as requested by the GOES Program Manager. This management structure is depicted in the following diagram.
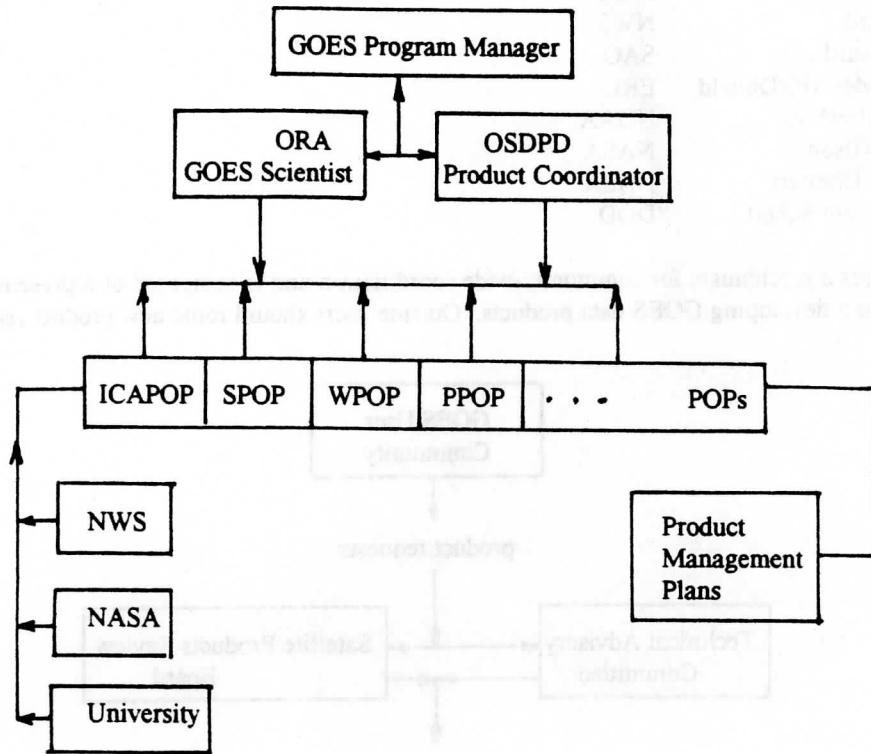
Presently Gerry Dittberner is the GOES Program Manager, Ben Watkins is the OSDPD Product Coordinator, and Paul Menzel is the GOES Scientist. The POPs with their respective co-chairs (one from research and one from operations) are listed below.

Image, Cloud, Aerosol	L. Stowe	B. Banks
Soundings	T. Kleespies	E. Burdsall
Winds	D. Gray	H. Carney
Precipitation	R. Scofield	N. Lyles
Oceans	B. Pichel	J. Sapper
Ozone	W. Planet	D. Bowman
Surface	D. Tarpley	M. Matson
ERB	H. Jacobowitz	J. Sapper
Calibration	M. Weinreb	R. Lawrence
Navigation	K. Kelly	E. Harrod

The GOES Program Manager is also served by the Technical Advisory Committee (TAC), which helps to guide GOES product research and development and to prioritize resource allocation. NESDIS will chair the committee which has representatives from NESDIS, SAO, NWS, ERL, NASA, DOD, FAA, and the university community; two meetings a year are suggested. Present members of the TAC are:

Paul Menzel (co-chair)	NESDIS
Jim Purdom (co-chair)	NESDIS
Ben Watkins	NESDIS
Leroy Spayd	NWS
Fred Mosher	NWS
Ron Gird	NWS
Ed Howard	SAO
Alexander MacDonald	ERL
Jamie Hawkins	NOAA
Greg Wilson	NASA
Dennis Chesters	NASA
Major Tom Schott	DOD

The TAC provides a mechanism for community-wide coordination and is composed of representatives from agencies using and developing GOES data products. Outside users should route new product requests through the TAC.

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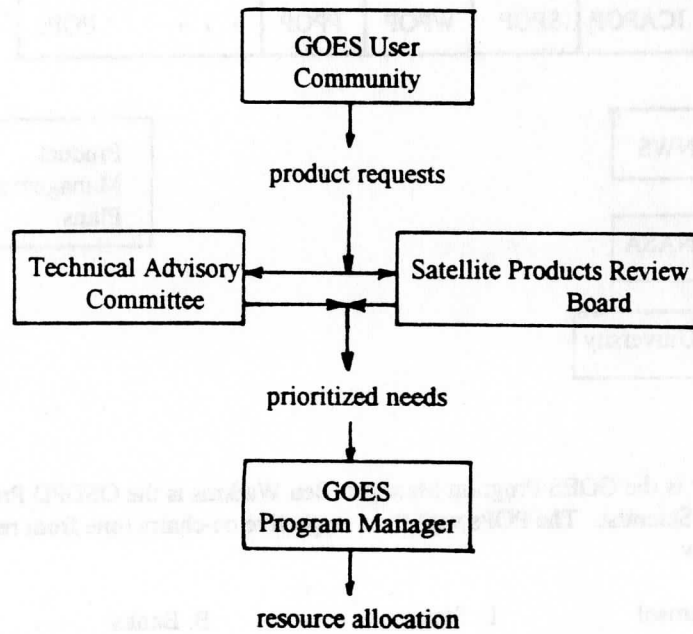
APPENDIX C. Product List

This list is current as of summer 1994 and will be updated periodically to incorporate new information.

PRODUCT	SENSOR/ SYSTEM	DEVELOPMENT/ IMPLEMENTATION	COVERAGE/ FREQUENCY	USER/ EVALUATOR
Cloud Parameters				
o Cloud Heights (Cloud Top Temp)	Imager/ RISC	Menzel/ Holland	FD/ 1ph	FAA & NCs/ NMC
o Cloud Amount (ASOS)	Sounder/ RISC	Menzel/ Holland	CONUS/ 1ph	WSFO & NCDC/ NWS
Enhanced Data Sets				
o GOES Projection (GOESTAP)	Imager/ GSS	Purdom/ Holt	sectors/ 2ph	NWS/ WSFO
o GOES Projection (WEFAX)	Imager/ DPSS	Ellrod/ Holt	FD/ 2ph	NWS/ NMC
o Lambert Conformal (AWIPS)	Imager/ CEMCSS	Purdom/ Holt	CONUS/ 4,8ph	NWS & NCDC/ MAR
(Routine, Warning mode)			Hawaii/ 2,4ph	
			P. Rico/ 2,4ph	
o Polar Projection (AWIPS)	Imager/ CEMCSS	Tarpley/ Holt	Alaska/ 2,4ph	WSFO & NCDC/ NWS
			N Hemis/ 2,0ph	
o Stretched Data (real time)	Imager/ OGE	Purdom/ Reynolds	Routine, Warning	NWS/ NCs
Atmospheric Parameters				
o Vertical Temperature Profiles (deg K)	Sounder/ RISC	Schmit/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC
o Layer Mean Virtual Temperatures (deg K)	Sounder/ RISC	Schmit/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC

PRODUCT	SENSOR/ SYSTEM	DEVELOPMENT/ IMPLEMENTATION	COVERAGE/ FREQUENCY	USER/ EVALUATOR
Atmospheric Parameters (cont)				
o Vertical Moisture Profiles	Sounder/ RISC	Schmit/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC
o Layer Precipitable Water (mm)	Sounder/ RISC	Schmit/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC
o Total Precipitable Water (mm)	Sounder/ RISC	Schmit/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC
	Imager/ RISC	Schmit/(Gray) Holland	NH/ 1ph	NCs & NCDC/ NSSFC
o Channel Brightness Temps (deg K)	Sounder/ RISC	Schmit/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ ORA
o Lifted Index	Sounder/ RISC	Schmit/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC
	Imager/ RISC	Schmit/(Gray) Holland	NH/ 1ph	NCs & NCDC/ NSSFC
o Geopotential Heights (m)	Sounder/ RISC	Schmit/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC
o Thermal Wind Profiles (m/s)	Sounder/ RISC	Schmit/ Carney	CONUS+/ 4pd	NCs & NCDC/ NMC & AOML
o Moisture Analysis (Interactive)	Imager/ RISC	Brown/ Carney	PD/ 4pd	NMC/ NMC
o Precipitation Estimates	Imager/ RISC	Scofield/ Lyles	CONUS+/ 8pd	NWS & NCDC/ NWS & NMC
o Precipitation Histograms	Imager/ DPSS	Scofield/ Hughes	30N-30S/ 8pd	NMC/ NMC
Data Bases				
o Imager	Imager DPSS SSEC	Hughes Metcalf	FD/ 2ph	NCDC/ SDPD
o Sounder	Sounder DPSS SSEC	Hughes Metcalf	CONUS+/ 1ph	NCDC/ SDPD

PRODUCT	SENSOR/ SYSTEM	DEVELOPMENT/ IMPLEMENTATION	COVERAGE/ FREQUENCY	USER/ EVALUATOR
Data Bases (cont)				
o Vicarious Cal (IR and VIS)	S and I/ DPSS	Weinreb/ SOCC		
o Long Term Cal (IR and VIS)	S and I/ PM	Weinreb/ SOCC		all/ all
Winds				
o Cloud Drift (low)	Imager/ NCCF	Hughes/(Gray) Schreitz	60N-60S/ 4pd	NCs & NCDC/ NMC
o Cloud Drift (high)	Imager/ RISC	Menzel/(Gray) Holland	60N-60S/ 4pd	NCs & NCDC/ NMC
o Moisture Drift (mid)	Imager/ RISC	Menzel/(Gray) Holland	60N-60S/ 4pd	NCs & NCDC/ NMC
o Deep Layer Mean	I and S/ RISC	Velden/ Holland	hurricane/ 4pd	NHC & AOML/ NMC & AOML

notation:

ph - per hour
pd - per day
CONUS+ - CONUS and adjacent oceans
FD - full disk
PD - partial disk

APPENDIX D. NOAA and University Organizations Responsible for Product Assurance

The following table summarizes the various NOAA affiliates and universities that have specific responsibilities for product assessment. Activities at each site include, but are not limited to, the indicated areas of responsibility. Where possible, lead individuals are also identified.

D.1.   Image, Cloud, and Aerosol

Atmospheric Sciences Branch (L. Stowe)	ICAPOP
Physical Sciences Branch (G. Ellrod)	WEFAX
	multispectral products
Physics Branch (N. Rao)	insolation
CIRA (J. Purdom)	image quality
(J. Dostalek)	multispectral products
CIMSS (A. Schreiner)	ASOS cloud products
(G. Wade)	multispectral products
Synoptic Analysis Branch (J. Lynch)	user feedback
WSFO Milwaukee/Sullivan (J. Eise)	ASOS cloud evaluation
	multispectral product evaluation
AWC (F. Mosher)	multispectral product evaluation
FSL (D. Birkenheuer)	LAPS impact studies

D.2.   Sounding

CIMSS (T. Schmit)	SPOP
	profiles and gradient winds
	derived product images
Sounding Implementation Branch (D. Gray)	software
CIRA (D. Hillger)	clustering
Synoptic Analysis Branch (J. Lynch)	user feedback
WSFO Milwaukee/Sullivan (J. Eise)	derived product evaluation
AWC (F. Mosher)	derived product evaluation
FSL (D. Birkenheuer)	LAPS impact studies
NSSL (B. Rabin)	derived product evaluation
NCEP Development Division (J. Derber)	RDAS/GDAS impact tests

D.3.   Winds

Sounding Implementation Branch (D. Gray)	WPOP
	software
Product Systems Branch (G. Hughes)	picture pair winds
CIMSS (S. Neiman)	upper level winds
(C. Velden)	deep layer mean winds
(P. Menzel)	cloud heights from H2O
CIRA (J. Weaver)	storm relative flow
(C. Vaughn)	geometric cloud heights
(J. Purdom)	mesoscale winds
University of Chicago (T. Fujita)	ground truth
Synoptic Analysis Branch (J. Lynch)	user feedback
TPC (M. Mayfield)	wind field evaluations
NCEP Development Division (G. DiMego)	RDAS/GDAS impact tests
AOML (J. Franklin)	model assimilation

D.4. Precipitation

Physical Sciences Branch (R. Scofield)	PPOP
(G. Vicente)	CST improvements
(D. Brown)	improved moisture bogus
Synoptic Analysis Branch (J. Lynch)	user feedback
NCEP Development Division (J. Derber)	model impact tests

D.5. Surface

Land Sciences Branch (D. Tarpley)	POP
	land surafce temperature

D.6. Ocean

Ocean Sciences Branch (B. Pichel)	POP
	SST
Physical Sciences Branch (E. Maturi)	SST
Marine Applications Branch	

D.7. Earth Radiation Budget

Atmos. Sciences Branch (H. Jacobowitz)	POP

D.8. Ozone

Physics Branch (W. Planet)	POP

D.9. Calibration

Physics Branch (M. Weinreb)	POP
SOCC	operational evaluation
CIMSS (S. Wanzong)	cal intercomparisons
CIRA (D. Hillger)	cal intercomparisons
NASA GOES Project	

D.10. Navigation

SOCC (K. Kelly)	POP
NASA GOES Project	

APPENDIX E.   References for further information on GOES and GOES Products

* NWS GOES-NEXT Requirements,
  April, 1983

* NOAA Technical Report NESDIS 33
  An Introduction to the GOES I-M Imager and Sounder Instruments
    and the GVAR Retransmission Format
  October 1987

* NOAA Technical Report NESDIS 40
  The GOES I-M System Functional Description
  November 1988

* Performance Specification for GOES-IJK/LM
  GSFC Revision 2A
  February 1989

* GOES I-M Operational Satellite Conference Proceedings,
  April 3-6, 1989

* Positive Characteristics of Viewing from Geostationary Orbit,
  7th Symposium of Meteorological Observations and Instruments,
  January 1991

* GOES-I Post-launch Test Plan,
  January 28, 1991

* GAO/NSIAD-91-252
  Report on Weather Satellites to the Committee on Science,
    Space, and Technology, House of Representatives
  July 1991

* Proceedings from the First Workshop on Wind Extraction from Operational
    Meteorological Satellite Data,
  September 17-19, 1991

* Preprints of the Sixth Conference on Satellite Meteorology and
    Oceanography,
  January 19, 1992

* GOES I-M Performance Overview,
  NASA GOES Project Briefing to Dr. Friday
  April 1992

* Proceedings from the Second Workshop on Wind Extraction from Operational
    Meteorological Satellite Data,
  December 13-15, 1993

* BAMS article "Introducing GOES-I"
  May 1994

APPENDIX F. Providing Information to the User Community

The value of GOES-8/9 technology to the warning and forecast program will be fully realized when forecasters are efficiently using the data and products with other observations and in numerical forecast models to improve weather operations and services. User information will be available through conference presentations, publications in peer review journals, technical reports, and technical information messages. Additional technical information regarding each product will be the responsibility of the POPs.

F.1. Conference Presentations

* American Meteorological Society (AMS) Meeting, January 1994

* AMS Conference on Satellite Meteorology and Oceanography; June 1994

* NWA Conference; October 1994

* American Meteorological Society (AMS) Meeting, January 1995

* Optical Society of America (OSA) Meeting, February 1995

* American Meteorological Society (AMS) Meeting, January 1996

F.2. Available and Planned Technical Reports

* NESDIS Guide to Satellite Products and Services Implementation
       NOAA Technical Memorandum NESDIS 38
       April 1994

* WEFAX Users Guide:
       August 1994

* GOES-I Data Collection System
       NOAA Technical Memorandum NESDIS 40
       June 1994

* GOES I-M Satellites and Data Flow:
       (invited article in Bulletin of AMS)
       NESDIS/SAO

* GOES Instrument Performance Summary for NWS and User Community:
       (invited article in Bulletin of AMS)
       NWS/NESDIS/SAO

* GOES I-M Instrument Performance:
       (NASA GOES Project Report)
       GSFC

* GOES I-M Calibration:
       (NOAA TM to be released soon)
       SOCC/ORA

* GOES-I Users Guide (GOES-TAP / NOAA PORT):
       (NOAA TM to be published before service begins)
       OSDPD

* GOES I-M Data User Guide (Archive data):
     (to be published)
     NCDC

* GOES Application Information Notes:
     (to be published as required by training program)
     ORA/NWS

F.3.   Formalized Training Functions

* Ongoing applied research training at selected WSFOs with RAMSDIS capability

* NWS SOO visits to NESDIS Centers of Excellence (CIRA, CIMSS, SAL).

* Two week training courses at the COMET
     March 1995, May 1996, July 1996, September 1996

* One day AMS short course on GOES
     28 January 1996

* Coordinated field experiments involving Coop Institutes and WSFOs
     Lake Effect Snow Experiment
     VORTEX
     FASTEX

* Computer Based Learning Modules developed by COMET
     Remote Sensing with the New GOES Imager, January 1996
     Using the GOES Sounder, December 1996

* CIRA Tutorial on GOES-8 Imager (computer disks)

* CIMSS Tutorial on GOES-8 Sounder (world wide web)

F.4.   Home Pages

* CIMSS GOES Home Page
     (http://oldthunder.ssec.wisc.edu/goes/goes.html)

* CIRA GOES Home Page
     (http://www.cira.colostate.edu/earthsta/overview.htm)

* NASA GOES Project Pages
     (http://climate.gsfc.nasa.gov/~chesters/goesproject.html)

* NOAA Weekly Report on GOES Project
     (http://140.90.207.25.8080/EBB/post/goeswky.asc)

APPENDIX G. Operational Schedules

Operational schedules for GOES-8/9 in the east covering CONUS and GOES-9 in the west covering PACUS are currently being implemented. All preliminary schedules include some elements of the following summary. CONUS indicates continental United States and PACUS indicates Pacific basin and western United States.

* imager
> routine mode: half hourly full disk and 15 minute CONUS (or PACUS)
> warning mode: half hourly northern hemisphere and 7.5 minute CONUS (or PACUS)
> one minute mode: 10 minute northern hemisphere followed by 20 one minute images

* sounder
> routine and warning modes: hourly CONUS coverage for ASOS and PACUS coverage for
> > numerical weather prediction models
> warning mode: three hourly duty cycle with
> > hour 1 and 2: repeat 15 minute coverage over active area
> > hour 3: one hour CONUS (or PACUS) coverage
> hurricane mode: three hourly duty cycle with
> > hour 1 and 2: repeat one hour CONUS (or PACUS) coverage
> > hour 3: one hour hurricane coverage for thermal wind support

NOAA plans to support three basic modes of operation: routine, warning, and one minute. In the imager routine mode, one full disk image is taken every three hours and images covering the contiguous United States (CONUS) are taken every fifteen minutes in the intervening times. The imager warning mode will be enacted when the onset of severe weather is imminent. In that mode, the CONUS is scanned eight times every hour for monitoring rapidly developing storms. For very special occasions, the one minute mode will enable a northern hemisphere image followed by 20 one minute images of about half of CONUS; this continues with interruptions for full disk imaging every three hours.

The GOES-8 sounder primarily covers CONUS and adjacent ocean areas every hour; cloud products in support of ASOS are the primary product. The GOES-9 is focused on hourly coverage of the PACUS; atmospheric temperature and moisture soundings for input to numerical forecast models will be generated. During periods of severe weather and/or tropical cyclone activity, interruptions for fifteen minute mesoscale/tropical coverage may occur. As with the imager, two basic modes of operation, routine and warning, have been suggested.

In the sounder routine mode, NOAA schedules one hour regional scans (CONUS coverage of 50 N to 22 N and 50 W to 110 W from GOES-8 and PACUS coverage of 49 N to 21 N and 110 W to 155 W from GOES-9). The sounder warning mode is enacted when the onset of severe weather is imminent; the location of the mesoscale coverage is adjusted as the weather situation dictates. In the warning mode, fifteen minute mesoscale scans are scheduled four times an hour over the area of severe weather for the first two hours. During the third hour, one fifteen minute mesoscale scan is followed by a 45 minute limited regional scan over the CONUS (or PACUS). This 3 hour schedule is repeated as long as the warning mode persists.

NOAA is initiating these new schedules with GOES-8 in the east and GOES-9 in the west, however, they are subject to change pending further review of alternate scanning strategies. The stunning performance of the GOES-8 imager in one minute imaging during the post-launch checkout has caused considerable rethinking of the planned operational schedules and raised the need for a third satellite in the middle. Additionally model impact studies are indicating the need for soundings over data void regions, not hourly CONUS coverage. The CIRA and CIMSS will be working with the satellite schedulers to evolve the present operational schedule to facilitate optimal use of the GOES-8/9 data by the NWS as well as to accommodate the needs of the science community as they explore improved products. Special schedules will be created to accommodate research projects or other users such as the Great Lakes Snow Experiment, FASTEX, tropical convergence, and NASA Space Shuttle support.

APPENDIX H. GOES Training Plan for National Weather Service

GOES-8/9 introduced a completely new design of three axes stabilized spacecraft, new sensors, and a new ground data processing/distribution system. To fully realize the benefits from this new GOES series, it is essential that the operational users are fully trained on how to use this new data. The NWS in conjunction with NESDIS/SAL, CIRA and CIMSS have developed a training plan for NWS users of GOES-8/9 data. The plan emphasizes bridging the technological leap for NWS field forecasters from visual interpretation of analog hardcopy or video images to the digital manipulation of GOES-8/9 imagery and sounder data on the Advanced Weather Interactive Processing System (AWIPS). AWIPS capabilities will allow the NWS operational forecaster community to finally exploit the advantages of combining high spatial and temporal resolution digital satellite data with radar, profiler and other digital data sources that will be part of the NWS Modernization .

To accomplish GOES-8/9 training a series of interactive multi-media Computer Based Learning (CBL) modules are being developed. The modules will cover the subjects of GOES-8/9 systems, analysis and interpretation of imager data, and understanding and using sounder products. The modules are being produced by the Cooperative Program for Operational Meteorology, Education and Training (COMET) in Boulder, Colorado with guidance from the CIMSS and CIRA. The CBLs are an extremely cost-effective way to train the entire operational workforce. Every NWS office and a large number of outside users already have the computer capabilities to utilize these modules. The modules will serve to train all the NWS operational forecasters. The NWS is conducting several intensive two week residence GOES courses at COMET (Mar 95, May 96, Jul 96, Sep 96) to train the Science and Operations Officer (SOO) and satellite focal points from each office. This will provide the trained experts at each NWS office to further lead the efforts on station.

Other external users such as TV meteorologists, universities, secondary school teachers, international users and the aviation community would also be trained by purchasing the CBL modules, videotapes and slide sets, as well as the AMS user workshops that are being provided annually.

A staff of three NOAA meteorologists, assisted by another four CIRA and CIMSS meteorologists, are planned to assist in the GOES-8/9 evaluation, develop instructional materials, design the CBLs, and instruct the residence courses. The training program for the NWS will be coordinated through a NWS manager in the NWS Office of Meteorology with a NWS meteorologists stationed at COMET. One NESDIS meteorologist will be stationed at CIRA to develop pre-AWIPS display capabilities of digital GOES data and to prepare imaging and sounding products for evaluation. An NSSL meteorologist will assist with training and WSR88D field experiment coordination.

The RAMSDIS units located at over 50 selected sites are being used to evaluate and validate the GOES-8/9 digital imagery, to conduct training in the operational forecast environment, and to participate in advanced product development. This effort is primarily support by CIRA and is aimed at reducing risks associated with AWIPS implementation by: a) establishing a learning curve within NESDIS and NWS on field site capability to use high quality satellite data; b) determining the type of training required for field forecasters to use this data; and c) assuring field forecaster input helps to set the priorities for day-1 product improvements.

This cross-utilization of staff among NWS and NESDIS will be an excellent example of how the synergy generated by the talents of both organizations working together can be used to improve the weather services of this country. The resources needed to accomplish this training will include hardware, staff and travel expenses. Cost estimates are in Appendix A.

APPENDIX I. Acronyms

ACARS - Aeronautical Radio Incorporated Communications Addressing and Reporting System
AOML - Atlantic Oceanographic and Meteorological Laboratory
ASOS - Automated Surface Observing Stations
ATS - Applications Technology Satellites
AVHRR - Advanced Very High Resolution Radiometer
AWIPS - Advanced Weather Interactive Processing System
CEMSCS - Central Environmental Satellite Computer System
CIMSS - Cooperative Institute for Meteorological Satellite Studies
CIRA - Cooperative Institute for Research in the Atmosphere
COMET - Cooperative Program for Operational Meteorology, Education and Training
CONUS - Continental United States
CST - Convective Stratiform Technique
DMSP - Defense Military Satellite Program
EMC - Environmental Modeling Center
EOL - end of life
ERL - Environmental Research Laboratory
ES - Earth sensor
FAA - Federal Aviation Administration
FASTEX - Front and Atlantic Storm Tracks Experiment
FSL - Forecast Systems Laboratory of ERL
FOV - field of view
GDAS - Global Data Assimilation System
GINI - GOES I NOAA-PORT Interface
GOES - Geostationary Operational Environmental Satellite
GSFC - Goddard Space Flight Center
GSS - GOES Sectorizer System
GVAR - GOES Variable (data format)
HIRS - High resolution Infrared Radiation Sounder
HIS - High resolution Interferometer Sounder
IDUC - Interactive Data Utilization Center
IFFA - Interactive Flash Flood Analyzer
IMC - image motion compensation
INR - Image Navigation and Registration
ISCCP - International Satellite Cloud Climatology Project
LAPS - Local Area Prediction System
LM - landmark
LO - Line Offices
MAR - Modernization and Restructuring
MIDAS - Multidisciplinary Interactive Display and Analysis System
MMC - mirror motion compensation
MTF - modulation transfer function
NASA - National Aeronautics and Space Administration
NCDC - National Climate Data Center
NCEP - National Center for Environmental Prediction
NEDT - noise equivalent temperature
NESDIS - National Environmental Satellite and Data Information Service
NHC - National Hurricane Center
NMC - National Meteorological Center
NOAA - National Oceanic and Atmospheric Administration
NOVA - NOAA Operational VAS Assessment
NSSFC - National Severe Storm Forecast Center
NWS - National Weather Service

NWSTC - National Weather Service Training Center
OAR - Office of Oceanic and Atmospheric Research
OGE - Operational Ground Equipment
ORA - Office of Research and Applications
OSDPD - Office of Satellite Data Processing and Distribution
POP - Product Oversight Panel
RAMMB - Regional and Mesoscale Meteorology Branch
RAMSDIS - Regional and Mesoscale Meteorology Branch Advanced Meteorological Satellite
                 Demonstration and Interpretation System
RDAS - Regional Data Assimilation System
SAL - Satellite Applications Laboratory
SAO - Systems Acquisition Office
SDAB - Systems Design and Application Branch
SOCC - Satellite Operations Control Center
SOO - Science Operations Officers
SPC - Storm Prediction Center
SPRB - Satellite Products Review Board
SRL - Satellite Research Laboratory
SSMI - Special Sensor Microwave Imager
TDU - Techniques Development Unit (at NSSFC)
TOVS - TIROS Operational Vertical Sounder
TPC - Tropical Prediction Center
VAS - VISSR Atmospheric Sounder
VDUC - VAS Data Utilization Center
VISSR - Visible and Infrared Spin Scan Radiometer
VORTEX - Verifications of the Origins of Rotation in Tornadoes Experiment
WSFO - Weather Service Forecast Office