

**GOES I-M PRODUCT ASSURANCE PLAN**

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Fifth Version  
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## **FOREWORD**

The initial draft of this plan was released 9 November 1992; a second version came out on 25 May 1993, a third followed on 20 December 1994, a fourth version was produced on 26 February 1996. The GIMPAP has been changing as plans and budgets evolve. This fifth version covers the years 1999 through 2002.

## EXECUTIVE SUMMARY

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 and -10 followed in May 1995 and May 1997. These new systems have capabilities to support NOAA programs, both operational and research, in the next decade. 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).

This NOAA GOES I-M Product Assurance Plan is intended to assure the viability of GOES 8/9/10 through M products, to improve initial products and develop advanced products, and to ensure integration of the improvements into NWS and National Environmental Satellite, Data, and 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.

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

- \* Identifies the necessary linkages between NESDIS and the NOAA organizational elements using GOES-8/9/10 through M data, products, and services.
- \* Defines GOES-8/9/10 products, as well as the testing and evaluation necessary to ensure product quality.
- \* Identifies procedures for user evaluation and feedback.
- \* Identifies product improvements and the research and development necessary for advancing to subsequent 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.

Efforts are focused on product validation, improved utilization, and user training in FY99, technique development for merging data from many components of a composite observing system and continued user training in FY00, 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.

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. Transition to the current GOES**

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.

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.

The GOES 8/9/10/L/M system is a significant advancement in our national geostationary environmental satellite capabilities. It must support US geostationary environmental satellite requirements, both operational and research to the mid 2000's. This plan details a three year program that will ensure that the opportunities offered by the GOES system for supporting NOAA's mission will be realized. This plan specifically addresses evaluation and validation of GOES products, product enhancements and evolution toward future products and sensor systems. Input has been coordinated with the National Environmental Satellite, Data, and 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-8/9/10 through M product stream is routinely available; (2) enhance the initial product data sets to take full advantage of the GOES system's capabilities and, (3) utilize the full capabilities of the improved GOES-8/9/10 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 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.

The phased implementation of NOAA's modernized observing system is well underway. This includes 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. New products will need to be developed that rely on information from the partnership of these high technologies that will accompany NWS modernization.

Prior to GOES-8 launch it was said that "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 GOES I-M Product Assurance Plans (GIMPAP) intends to coordinate efforts to assure that the capabilities of the GOES system are fully exploited and the actions necessary to realize the improvement in NWS products and services are continued.

Data processing systems have evolved to accommodate the new opportunities offered by GOES; an expanded NESDIS product suite has come on line (the current list is summarized in Appendix C). New data processing and analysis systems are being placed at NWS National Centers and field offices that will make it possible to exploit the potential of a frequent interval observing system from geostationary satellites.

Establishing the means and methods of effectively integrating GOES into operational service programs requires the coordinated and combined efforts of research, development and operational units within NOAA. The improved products and services from the GOES satellites are making important contributions to a number of national programs.

### **1.3 Purpose of Product Assurance Plan**

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

This plan presents the procedures and plans relevant for GOES data and products in three key areas: (a) scientific evaluation; (b) user assessment; and (c) product evolution. Section 2 presents the product testing and development activities in some detail. Section 3 indicates how the integration into operations will occur. Section 4 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 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-8/10 schedules. Appendix H details a training plan for the NWS and other users. An acronym list occupies Appendix I.

## **2. 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 remote sensing capabilities provided by the GOES satellite series. 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.

An ongoing effort is required. The three 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.

## 2.1. Characterizing and Validating Instrument Performance

GOES-8/9/10 data are still being compared against data from 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. Periodic intercalibrations of GOES with these polar orbiting systems are being conducted and the results are presented to the annual meeting of the Coordinating Group for Meteorological Satellites. In addition, radiance biases with respect to radiosonde measurements are evaluated monthly. Image navigation characteristics are monitored daily. Overall the performance has been better than anticipated or specified.

### 2.1.1 Imager Performance

The GOES imagers are exceeding radiometric requirements. Inflight determinations of noise levels indicate that all bands on the imager are meeting specifications. The following table shows inflight noise performance of the GOES-8/9/10 imagers versus Meteosat-7 and GMS-5.

The visible band performance continues to excel, where 10 bit data from silicon detectors shows a wide dynamic range and good detector to detector consistency. GOES water vapor images are still the most significantly enhanced over previous GOES-7 images. 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-8/9/10 Imager, Meteosat-7, and GMS-5 performance (with GOES specified noise values indicated)

Band	Bit Depth	Resolution	Noise
	G10/ G9/ G8/ M7/ G5	G10/ G9/ G8/ M7/ G5	G10 (spec) /G9 /G8 /M7 /G5
Visible			counts
.65 um	10 / 10 / 10 / 8 / 6	1 / 1 / 1 / 2.5 / 1.25 km	3 (7) / 3 / 3 / 1 / 1
Infrared Windows			(deg C at 300 K)
3.9 um	10 / 10 / 10 / X / X	4 / 4 / 4 / X / X km	.11 (1.4) / .12 / .23 / X / X
10.7 um	10 / 10 / 10 / 8 / 8	4 / 4 / 8 / 5 / 5 km.	.09 (.35) / .09 / .14 / .18 / .11
12.0 um	10 / 10 / 10 / X / 8	4 / 4 / 16 / X / 5 km	.19 (.35) / .19 / .26 / X / .13
Water Vapor			(deg C at 230 K)
6.7 um	10 / 10 / 10 / 8 / 8	8 / 8 / 16 / 5 / 5 km	.14 (1.0) / .11 / .22 / .35 / .40

The GOES-8/9/10 imagers are close to meeting their pointing requirements over the continental United States (CONUS) sector; various motion compensations are working well. The GOES-8/9/10 image navigation systems 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.

### 2.1.2 Sounder Performance

The GOES-8/9/10 sounders are exceeding their radiometric noise requirements in the shortwave and midwave channels; GOES-10 is the first in the series to be meeting requirements also 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: Noise Comparison for GOES-8/9/10 Sounder and GOES-7 VAS and NOAA-12 HIRS

Wavelength (um)	Ch	NEDT G-10(9) (290K)	NEDR			(spec)	Improvement G9/G7 (FOV adjusted)	G9/N12
			G-8 (mW/m2/ster/cm-1)	G-9	G-10			
Longwave								
14.7	1	0.41(0.75)	1.63	1.20	0.66	(0.66)	7.7	1.2
14.4	2	0.31(0.49)	1.41	0.80	0.51	(0.58)	5.6	1.3
14.1	3	0.24(0.36)	0.94	0.56	0.39	(0.54)	2.5	1.2
13.9	4	0.24(0.28)	0.65	0.46	0.39	(0.45)		1.0
13.4	5	0.21(0.27)	0.74	0.45	0.34	(0.44)	3.1	0.9
12.7	6	0.09(0.12)	0.32	0.19	0.15	(0.25)	5.9	
12.0	7	0.06(0.08)	0.21	0.13	0.09	(0.16)		
Midwave								
11.0	8	0.09(0.07)	0.15	0.10	0.14	(0.16)	1.3	2.1
9.7	9	0.09(0.07)	0.20	0.11	0.13	(0.33)		2.9
7.4	10	0.10(0.09)	0.091	0.076	0.083	(0.16)		5.6
7.0	11	0.07(0.07)	0.091	0.047	0.053	(0.12)	25.0	8.3
6.5	12	0.17(0.15)	0.119	0.086	0.092	(0.15)	3.0	
Shortwave								
4.57	13	0.07(0.09)	0.012	0.008	0.006	(0.013)		1.6
4.52	14	0.05(0.08)	0.011	0.007	0.004	(0.013)	7.7	1.1
4.45	15	0.05(0.08)	0.012	0.006	0.004	(0.013)	11.1	1.4
4.13	16	0.06(0.08)	0.004	0.003	0.003	(0.008)		
3.98	17	0.06(0.10)	0.005	0.003	0.002	(0.008)	4.8	1.4
3.7	18	0.06(0.05)	0.002	0.001	0.001	(0.004)		2.1

FOV sizes

GOES-8/9/10 8 km  
 GOES-7 7 km (14km for very longwave and shortwave)  
 HIRS 17 km

## 2.2. Evaluation/Validation of Derived Products

### 2.2.1. Calibration

The calibration algorithm of the infrared radiances is being validated as part of the scientific evaluation. To validate the IR radiances, the GOES measurements are being compared to collocated radiance measurements from other sensors (on board the NASA ER-2 as well as the polar orbiting NOAA series) and with forward calculations based on radiosondes or model analyses. 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 0.3 C; comparisons for the sounder are found in the following table. In 1997, radiances were compared from both leo and geo sensors with near nadir view of a scene containing mostly clear and some cloudy sky area. Differences in mean scene radiances are corrected for spectral response differences through clear sky forward calculation. The corrected mean differences are attributed to calibration differences. Calibrations within 0.25 C are practical with careful quality control. Intercalibration of all geostationary satellites can be accomplished with one black body. Initial results suggest that all the geostationary infrared window sensors are within 0.4 C of the HIRS (GOES-8/9 are 0.2 C warmer, GMS-5 is 0.1 C colder, and Meteosat-6 is 0.4 C colder). Diurnal and seasonal changes in the infrared

calibration are under investigation by the NESDIS Satellite Operations Control Center (SOCC) with assistance by the Soundings and Instrument Team.

Table. Brightness temperature differences for HIS (High spectral resolution Interferometer Sounder) minus GOES-8 sounder bands with correction for viewing geometry.

GOES-8 Sounder Band	Brightness Temperature Difference (K)
1	1.1
2	1.3
3	1.6
4	-0.3
5	0.1
6	-0.7
7	-1.2
8	-0.9
9	na
10	0.1
11	-0.4
12	0.8
13	-0.1
14	0.1
15	0.3
16	0.2
17	0.4
18	na

Table. HIRS – GEO IR window calibration differences (in brightness temperatures)

HIRS – GEO IRW	$\Delta T_b$ (K)
GOES-8/9	- 0.2 C
GMS-5	0.1 C
Meteosat-6	0.4 C

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 visible data. A target data base has been developed that is supplying the data arrays (daily, hourly, seasonally) for selected sites that serve for the visible calibration. The utility of bright clouds for visible reference is also under consideration. To date a 4.5% fall off in visible detector response per year has been found for GOES-8. For GOES-9 this was 2 % per year before termination of operations. GOES-10 is under study. The NESDIS Soundings and Instrument Team is assuming responsibility for the visible calibration. The Calibration Oversight Panel coordinates these activities.

### 2.2.2. Navigation

The navigation of GOES images is under evaluation through deviations in landmark registration; these are catalogued diurnally and seasonally, with corrections suggested to the Operational Ground Equipment periodically. To date navigation within 1.5 km is typical. The Navigation Oversight Panel coordinates this activity.

### 2.2.3. Image, Cloud, and Aerosol

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



The GOES imaging system has the capability of providing a wide variety of image products. The five imager channels are: (1) 0.62  $\mu\text{m}$  (vis) used for imaging clouds, snow and ice, and land features; (2) 3.9  $\mu\text{m}$  (shortwave infrared window) used for identifying fog/stratus, cloud vs snow, fires/volcanoes, and sea surface temperature (SST) determination; (3) 6.7  $\mu\text{m}$  (water vapor channel) used for synoptic analysis, upper tropospheric humidity, and finding convection; (4) 10.7  $\mu\text{m}$  (longwave infrared window) used for cloud tracking, locating cloud tops, and SST determination; and, (5) 12.0  $\mu\text{m}$  (split window) used primarily for low level moisture identification and SST determination.

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.

While awaiting full implementation of AWIPS, a number of RAMSDIS units have been distributed to enable access to digital GOES 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. CIRA has implemented a virtual laboratory with the RAMSDIS units to increase collaborative interactions for users of GOES data. 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 80 RAMSDIS units have been deployed.

CIRA continues with several specific areas of investigation. They include (1) investigations of 5-minute interval and other rapid scan images for severe storm nowcasting, hurricane research, early fog detection, and depiction of snow storms, (2) combination of satellite and radar products for improved depiction of rainfall, (3) cloud height assignment from shadows and stereographic techniques, (4) principal component analysis of the information content of the imager spectral bands, (5) investigation of leo and geo combined image products, and (6) evaluating the utility of the different spectral bands or volcanic ash detection.

The University of Virginia is also studying GOES imager displays of temperature and water vapor. Through operational use of GOES data in support of field campaigns, UVa discovered a method to remove the significant temperature dependence in the GOES water vapor channel to derive specific humidity, a useful dynamic tracer for mid-tropospheric ozone. Upper tropospheric CO<sub>2</sub> sensitive spectral band brightness temperatures are being subtracted from upper tropospheric H<sub>2</sub>O sensitive spectral band brightness temperature in an attempt to separate moisture from temperature variations in the atmosphere. UVa is exploring applications as an operational tool of value to the atmospheric chemistry community.

The Soundings and Instrument Team, 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 has been on insolation and albedo in the Mississippi drainage basin in support of the Global Energy and Water Cycle Experiment (GWEX). Other evolving products, either planned or under investigation, are given in section 4.4.

CIMSS has developed and validated a GOES cloud product through comparison with ground observations with NWS participation. This cloud activity is motivated by the NWS introduction of the Automated Surface Observing System (ASOS) nationwide; there already are many ASOS sites in the operation. The cloud information from the

ASOS equipment is limited to altitudes below 12,000 feet, thus the GOES provides supplemental information about cloud cover above 12,000 feet. The combined ASOS/satellite (ASOS/SAT) system depicts cloud conditions at all levels. The satellite cloud information is derived using sounder data with the CO2 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 WSFOs at Milwaukee/Sullivan and LaCrosse are participating in the evaluation/validation of the ASOS/SAT system. There are already ten ASOS units installed in Wisconsin and the Milwaukee/Sullivan and LaCrosse WSFOs are 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.

#### **2.2.4. 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, CAPE, 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 41 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 (or 3x3) array of FOVs whenever 9 (or 4) 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. CIMSS is largely responsible to developing the techniques to select clear FOVs and retrieve temperature profiles; in addition, CIRA is investigating sounding strategies based on radiance clustering and structure function analyses.

Vertical moisture (specific humidity) profiles are obtained in the simultaneous retrieval, and thus are provided at the same levels as temperature. 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). Three precipitable water layers are integrated from retrievals of specific humidity. These and the total precipitable water are 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 (or 3x3) 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.

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. CAPE, another measure of atmospheric instability, is also provided.

The geopotential height of the pressure level as derived from a 1000 mb height analysis (from the NCEP 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.

Thermal winds can be 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 (EMC 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 retrieval gridpoints centered at the gridpoint closest to each retrieval. Wind estimates are provided from 700 to 400 mb.

Derived product imagery can be produced from either the imager or the sounder. The current GOES derived product images (total precipitable water, lifted index, and cloud top pressure) are produced using the sounder. Derived product imagery is formed from pixel-by-pixel retrievals of atmospheric temperature and moisture profiles wherever the atmosphere is quasi-clear and cloud cover is superimposed in the remaining pixels.

The overall quality of these products has been assessed in case studies and comparison of information content with forecast model backgrounds. The results have been published in Menzel, W. P., F. C. Holt, T. J. Schmit, R. M. Aune, A. J. Schreiner, G. S. Wade, G. P. Ellrod, and D. G. Gray, 1998. Application of the GOES-8/9 soundings to weather forecasting and nowcasting. Bull. Amer. Meteor. Soc., 79, 2059-2077. Some of the evaluation results are repeated here.

GOES sounder moisture content over broad layers in the troposphere were compared to those inferred from radiosonde measurements. The total column water vapor RMS difference with respect to radiosondes for this eleven month period in 1996-97 has been reduced from 3.3 mm for the forecast first guess to 2.6 mm for the GOES retrievals, roughly an improvement of 20%. It is found that GOES is drier than the radiosonde in the mean by 0.7 mm in the lowest layer (surface to 900 hPa) and more moist in the mean by 0.3 mm in the middle (900 to 700 hPa) as well as the upper (700 to 300 hPa) layers; GOES improves upon the model first guess in all layers in the RMS difference by 0.1 to 0.4 mm. The atmospheric stability inferred from these eleven months of profiles has also been evaluated. GOES lifted indices (LI) of air parcels elevated to 500 hPa are found to be less stable in the mean by 0.6 C from those inferred from radiosondes with a RMS difference of 2.2 C. The numerical model first guess is 0.4 C less stable in the mean and shows an RMS difference of 2.4 C with respect to radiosonde determinations. In the vicinity of radiosondes, the GOES depiction of atmospheric stability is improving upon the first guess information from the forecast model. More significant is the fact that much larger differences (greater than 100%) between GOES soundings and model forecasts often occur over oceanic regions where radiosondes are unavailable; this indicates a much larger potential for GOES soundings to influence the forecast model in data sparse regions.

Table. Verification with respect to radiosondes of the NGM forecast first guess and the GOES-8 three layer moisture retrievals for April 1996 to February 1997. Only 00 UTC retrievals are included. The bias and root-mean-square (RMS) scatter about the bias are compared to radiosondes (in mm). The collocation distance within 0.25 degrees. Sigma is the ratio of the pressure over the surface pressure. Sample size is 1488.

	Guess		Retrieval	
	Bias	RMS	Bias	RMS
Total Water Vapor	-0.3	3.3	-0.1	2.6
WV1 (Surface to .9 sigma)	-0.9	1.6	-0.7	1.5
WV2 (0.9 to 0.7 sigma)	0.2	2.1	0.3	1.7
WV3 (0.7 to 0.3 sigma)	0.3	1.4	0.3	1.1

These sounder validation activities are focused at CIMSS. The data evaluation periods have overlapped with several special field programs (e.g. the NASA ER-2 flying as a pre-Earth Observing System testbed) so that extensive airborne and ground based observations have been available for intercomparison and assimilation. In addition there is an ongoing validation effort of GOES sounder profiles at the Cloud and Radiation Testbed (CART) site in Oklahoma; GOES temperature and moisture information is being compared to ground based interferometer, GPS, microwave radiometer, and class sondes routinely.

Hourly processing of the sounding and imaging data started in 1995. Derived product images of layer mean moisture as well as cloud top pressure are being displayed on the CIMSS home page at [http://cimss.ssec.wisc.edu/goes.html](http://cimss.ssec.wisc.edu/goes/goes.html).

In 1999, the effort on soundings will focus on inclusion of NOAA-15 microwave soundings to form composite sounding fields from leo and geo and collaboration with EMC to conduct model impact studies. GOES data assimilation activities will use both the CIMSS Regional Assimilation System (CRAS) and the EMC 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 hourly GOES versus twelve hourly GOES will be run to ascertain the benefit of geostationary observations.. In collaboration with EMC, the 3-layer moisture retrieval impact on the Eta model will continue to be studied using GOES retrievals over the CONUS, Gulf of Mexico, and Pacific basin. GOES cloud information will be used to initialize the Eta model cloud fields. CIMSS will also assist with efforts at direct radiance assimilation.

Investigation of the GOES ability to depict boundary layer properties is still pending. Techniques will be developed utilizing the shortwave channels on GOES 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, NSSL will be included in the evaluation through pilot demonstration programs. This work will be conducted primarily by the CIMSS, in collaboration with the CIRA, the NESDIS Sounding and Instruments Team and the EMC.

### **2.2.5. Winds**

Currently, operational winds are derived four times daily from imager data, from a sequence of 3 half hourly visible and infrared window images. The winds are calculated by a three-step objective procedure that are also applied to GOES 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 EMC forecasts, time and space interpolated to the location of the target. An initial guess motion is used, based on EMC 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 H<sub>2</sub>O intercept method. These initial height assignments are quality controlled and a few 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.

Winds from moisture imagery (6.7  $\mu\text{m}$  from the imager , 7.0 and 7.4  $\mu\text{m}$  from the sounder) 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. Water vapor motion vectors are labeled as clear sky or cloudy sky to assist with NWP interpretation of the motion; clear sky represents a layer mean motion while cloudy sky represents cloud top level motion.

Combined cloud drift, moisture drift, and thermal gradient winds have been studied by the Atlantic Oceanographic and Meteorological Laboratory and the Tropical Prediction Center in the context better depiction of hurricane trajectories. Results of tracking cloud and WV features in the GOES images has been very encouraging; impact tests on Navy and GFDL models indicate that a 10 to 20% improvement is achieved in hurricane 72 hour trajectory forecasts from inclusion of the GOES winds.

Table: Example recent forecast results using GOES winds in the Geophysical Fluid Dynamics Laboratory (GFDL) models from Tropical Cyclones Jeanne and Ivan (a total of 14 cases). GFDW is with satellite winds, GFDR is without satellite winds, VBAR is the operational barotropic model, A90L is the operational statistical-dynamic model (1990), and CLIP is climatology and persistence. Forecast trajectory errors are in kilometers.

	GFDW	GFDR	A90L	VBAR	CLIP
12 hr	91.	92.	102.	115.	104.
24 hr	154.	196.	197.	213.	220.
36 hr	203.	274.	291.	305.	351.
48 hr	240.	278.	336.	377.	445.
72 hr	348.	387.	545.	593.	729.

In 1999, FPDT is evolving the operational winds product to production every three hours and inclusion of EUMETSAT quality indicators. Validation continues with direct comparisons of collocated computed cloud motions and radiosonde observations. It reveals GOES 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. Work continues with EMC and CIMSS collaborating on improved utilization of the high density winds in the GDAS; results comparable to those achieved at GFDL are the goal.

Further evaluation of the GOES winds with a statistical structure function analysis has been underway at the Global Hydrology and Climate Center (GHCC) at Marshall Space Flight Center (MSFC). In application to the NESDIS water vapor winds, the winds fields were found to contain random errors which ranged from 1.0 - 7.0  $\text{ms}^{-1}$  for the u and v wind components, depending on the type of editing imposed in the auto-editing procedures. These error values are comparable to or lower than error estimates from other wind techniques. A detailed assessment of the NESDIS auto-editing procedures was performed for the water vapor winds. In a typical application, the auto-editor reduced the number of initial winds (unedited) by nearly 75%, and at times the scheme artificially skews the pressure-height reassignment. The WV winds better defined the large scale gradients in the wind fields than the infrared winds. The infrared winds seemed to resolve a bit more of the small scale motions than the water vapor winds. Trade-offs between spatial resolution, target/tracking template size and the quality of the resulting data have been investigated. It has been found that visible 1 km images produced the best wind fields with 5 minute loops, infrared window 4 km images with 15 minute loops, and water vapor 8 km images with 30 minute loops. Further studies are planned.

The recent Workshops on Wind Extraction from Operational Meteorological Satellite Data (Sep 1991; Dec 1993; June 1996, Oct 1998) suggested several new wind algorithm 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 CO2 slicing technique), (2) tracking features in more images with shorter time separations, (3) further 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), (5) tracking features in the retrieval fields rather than the radiance observations, and (6) balancing mass and motion fields in NWP models through direct assimilation every hour of the water vapor radiances.

At the most recent International Winds Workshop, the winds community agreed that accomplishments since 1991 include a) more uniform height assignments with IR-WV intercept approach, b) increased successful use of water vapor and visible winds, c) standardized reporting of AMV versus radiosonde observation differences, d) introduction of common quality indicators for AMVs, e) initiation of BUFR dissemination of AMVs with additional quality information, f) demonstration of positive impact of high density winds in field programs and case studies (notably in tropical cyclone trajectory forecasts), and g) demonstration of improvement in AMV derivation with more frequent observations (implications for revised satellite operation schedules are being explored).

The winds work represents an ongoing activity largely centered at the two NOAA cooperative institutes, CIMSS and CIRA, working closely with EMC. The Winds POP coordinates activities in this area.

### 2.2.6. Precipitation

One of the missions within NESDIS is to provide support to the National Weather Service (NWS) in Quantitative Precipitation Forecast (QPF) and Estimation (QPE). This support involves developing conceptual models and products for flash flood and heavy precipitation estimation and forecasting as well as furthering our knowledge on interpreting associated features in the satellite imagery. Additionally, these results must be transferred to the user community via workshops, conferences, technical and refereed papers. In response, the GOES automated estimator of precipitation has been developed and is being implemented into operations. It replaces the Interactive Flash Flood Analyzer (IFFA). This is being accomplished by the NESDIS Hydrology Team and is coordinated with the Precipitation POP.

Initial version of the autoestimator has been developed to include the following capabilities: (1) infrared window rain rate curve, (2) supplemented with rain mask based on available atmospheric total precipitable water vapor relative and humidity (PWRH inferred from the EMC forecast model or the sounder products), (3) complemented further by rain/no rain masks based on cloud growth and cloud gradients inferred from the IR window brightness temperatures, (4) parallax correction for viewing angle, (5) option for manual adjustment of the rain rate curve for individual precipitation systems (warm and cold tops) based on Equilibrium Level Temperatures and radar/rain gauges, and (6) orographic adjustment. Autoestimator 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 autoestimator accuracy have been gathered and published in Vicente et al (1998).

The coming years will extend the autoestimator to fifteen minute image loops, incorporate visible as well as the other infrared radiances on the imager, and make use of ancillary data such as WSR-88D, rain gauges, and microwave radiances from SSM/I and AMSU. Studies of a neural network/expert system for GOES instantaneous rain rates are also planned.

Another GOES rainfall algorithm has been investigated also. The GOES Multi-Spectral Rainfall Algorithm (GMSRA) attempts to resolve deficiencies typically found with IR only algorithms; errors due to cirrus contamination, poor detection of light warm rain, and bias towards tropical air masses, to cite a few. The multi-spectral approach uses combined information from visible (0.65  $\mu\text{m}$ ), near-infrared (3.9  $\mu\text{m}$ ) and infrared (6.7  $\mu\text{m}$ , 11  $\mu\text{m}$ , and 12  $\mu\text{m}$ ) GOES measurements. For daytime rainfall, the first step consists of identifying optically thick clouds having a visible reflectance greater than 0.40. Non-precipitating cirrus is screened empirically using a gradient temperature based on the 11  $\mu\text{m}$  channel and the effective radius of cloud particles near their tops is derived from the reflected solar irradiance at 3.9  $\mu\text{m}$ . Negative Brightness Temperature Difference (BTD) IR-WV(11  $\mu\text{m}$  - 6.7  $\mu\text{m}$ ), which corresponds well with rainfall areas for very deep convective cores (Inoue, 1997), is also used for the identification of rain for cloud tops colder than 230K. The algorithm uses the effective radius to separate raining from non-raining warm clouds during daytime. The algorithm relies on IR and WV only during nighttime and rainfall is estimated for clouds having brightness temperatures colder than 230K. For each pixel classified as containing raining clouds, the associated instantaneous rain rate is computed using a pre-calibrated probability of rain and mean rain rate for cloud top brightness temperature (11  $\mu\text{m}$ ) groups of 10K. The rain rate is obtained by the product of the probability of rain and the mean rain rate. A cloud growth rate, defined as the difference between the current and the previous images, and a correction factor accounting for the available moisture are used to adjust the rainfall estimates. Experience to date shows that this model compares quite well to radar data particularly in light rain areas, and generally agrees in magnitude with the Stage IV Multi-sensor (radar and gauge) analysis of NCEP. In high rain rate areas it is generally less than the auto-estimator - however, the auto-estimator frequently overestimates in high rain areas. Estimates from this model are produced every half hour and are routinely output to the flash flood home page as 6 and 24 hour accumulations. Routine statistical evaluations are provided daily for selected cases, along with various versions of the Auto-estimator. Overall it is competitive with the auto-estimator; sometimes showing better statistical results and sometimes poorer results. Qualitatively, the GMSRA appears to agree well in spatial distribution and magnitude with NCEP Stage IV Analysis, which blends radar and gauge data



for hourly and accumulated rainfall. More detailed case studies are needed to assess the true strengths and weaknesses of the model. The work was submitted to the Journal of Applied Meteorology and is currently under revision for re-submission.

Over the next two years the following will be started: 1) High quality radar rainfall data will be collected for seasonal and regional calibration of the GMSRA, probably from GWEX Continental scale International Project (GCIP) and other sources. 2) The PWRH adjustment factors will be refined. The PWRH adjustment is ad hoc and recent work indicates that the adjustment factors may be important only at specific locations and times. This could have a dramatic impact on the final precipitation estimates especially in relatively dry locations. An investigation into a moisture correction will be made to arrive at a quantitative adjustment for specific seasons and locations. 3) AMSU and SSM/I microwave data will be included to the model. Initial efforts have been started to use the microwave data especially over water to help train the algorithm. Over land the microwave provides information about the ice content of clouds which can help in refining the precipitation estimates. The challenge will be to develop procedures for incorporating the low spatial and temporal resolution microwave data with the high resolution GOES data. Various procedures such as histogram matching techniques and spatial and temporal interpolations will be investigated. 4) Use of the 3.9  $\mu\text{m}$  data will be extended to nighttime for warm rain. 5) Validation against TRMM data will be started.

Model impact studies are planned at the Cooperative Institute at Penn State University. They will be using the NCAR Mesoscale Model to study effective use of the NESDIS automated precipitation estimates and other satellite products in mesoscale modeling to improve quantitative precipitation forecasting. Project plans include adapting the Soil Hydrology Model (SHM) kernel of the MM5 model to accept autoestimator rain data and running the MM5 and SHM to determine optimal grid resolution, optimal cumulus parameterization scheme, and land surface schemes.

### **2.2.7. Surface Products**

There are currently no operational surface products from GOES. However, research is ongoing in several product areas, such as insolation, land surface temperature, and fire detection. GOES estimates of insolation and clear sky land surface temperature are being developed in support of a Land Data Assimilation System (LDAS). For several years the GCIP project in the Office of Global Programs has supported development of products from GOES that support NCEP and the GCIP science community. In the spring of 1999 NCEP will begin running a Land Data Assimilation System (LDAS) that is aimed at testing, validating and ultimately implementing operationally, a method for estimating soil moisture fields over the Eta domain. Three surface physics schemes will be tested in the LDAS. Quantities that force the surface energy and water balance models are precipitation, net radiation, air temperature, humidity, and wind speed. In the LDAS, precipitation and shortwave radiation will be determined from measurements, and the remaining variables from the Eta model. The shortwave radiation (insolation) will be derived from GOES observations. Insolation is one of the most important forcing variables and one of the most poorly estimated from the Eta model itself. The surface energy balance models all generate surface (skin) temperature as one of the derived variables. A good diagnostic of the accuracy of the surface physics is by comparing the derived surface temperature with that observed from satellites. Validation and diagnostic analysis of the land surface schemes will make use of surface temperature retrieved from the GOES imager. This form of validation has already proved useful in trouble-shooting the Eta model surface package, and promises to do the same for the LDAS.

The infrared window bands (4 and 11  $\mu\text{m}$ ) on the GOES-8 imager have proven to be very useful for fire detection. The short-wave window has four times and the long-wave window has twice the spatial resolution available on previous GOES platforms while maintaining similar radiometric performance. The spatial resolution of the 4  $\mu\text{m}$  band on previous GOES platforms was the primary limiting factor in fire detection. The noise of the GOES-7 VAS sensor in a typical scene (about .25 C in the 4  $\mu\text{m}$  band and .15 C in the 11  $\mu\text{m}$  band) limited detectable fires to .03  $\text{km}^2$  with a mean temperature of 450 K. In South America the smallest fires detected with the GOES-7 fire algorithm were about .1  $\text{km}^2$ . For GOES-8, with roughly the same noise constraints, the minimal detectable fire burning at 450 K is .002  $\text{km}^2$ . For the 1995 biomass burning season in South America fires as small as .01  $\text{km}^2$  have been detected. The enhanced capabilities of the GOES-8 imager make it much more useful for detecting and characterizing biomass burning not only in the Amazon Basin of South America, but also in the temperate and

boreal forests of the United States and Canada. While fires in South America are usually a clear sky dry weather human initiated phenomenon, in North America they are often initiated by lightning in cloudy conditions; hence the fire detection algorithms will be substantially different. CIMSS is working on an extension of the South American Automated Biomass Burning Algorithm (ABBA) to the North American fires. Validation is being pursued with the US Forest Service and the Canadian Environment Service.

These surface products are the responsibility of the NESDIS Surface and Atmosphere Team and are coordinated with the Surface Products Oversight Panel.

### **2.2.8. Ocean Products**

There are currently no operational ocean products from GOES, but sea surface temperature is being investigated as a potential operational product. The inflight imager calibration accuracy, stability, and line-to-line, channel-to-channel, and scene-to-scene variations have been found to be adequate for SST calculation. The GOES sea surface temperature has indicated a strong diurnal cycle in radiating temperature from calm waters. Additionally it has been shown 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 Soundings and Instruments Team are working on this merged leo-geo product.

The large diurnal excursions in the GOES SST (2 to 3 C in ocean areas with surface winds less than 5 m/s) have significant implications for NWP models that are assimilating GOES radiances directly; forward calculations have to accommodate a diurnal change in SST. Further, the GOES advantage of many observations of the same FOV per day (ten times more than the polar orbiters) enables a robust cloud-filtered temporal composite SST product for the U. S. coastal areas which can assist the Coast Watch part of the Coastal Ocean Program. A development effort is underway at CIMSS and NESDIS Ocean Research and Applications Division (ORAD) to bring an operational product on line. Their activities will be coordinated with the Ocean Products Oversight Panel.

### **2.2.9. Earth Radiation Budget**

There are currently no operational earth radiation budget products from GOES. However, based on knowledge acquired from HIRS, AVHRR, and ERBS, the University of Maryland Cooperative Institute for Climate Studies (CICS) is exploring a number of potential GOES products. CICS will be generating GOES monthly averaged clear and all sky outgoing longwave radiation, clear sky downward longwave flux, and clear sky layer (1000-700, 700-500, 500-250, 250-10 mb) cooling rates as a function of time of day at 30 kilometer resolution. Investigations are beginning into climate phenomena with large diurnal variations and synergy with the International Satellite Cloud Climatology Project. The NESDIS Soundings and Instruments Team participates in ISCCP; activities in this area will be coordinated with the Earth Radiation Budget Products Oversight Panel.

### **2.2.10 Ozone**

There are currently no operational ozone products from GOES. However, the GOES sounder has an ozone sensitive channel at 9.6 um and there continues to be a major interest in diagnosing the origin of mid-tropospheric ozone. Ozone is an important oxidant that can influence the concentration, distribution, and trend of radiatively active atmospheric trace gases, demonstrating a link between chemistry and climate. For example, a major new initiative out of the Atmospheric Chemistry Division at NCAR is proposing a field campaign in the year 2000 entitled "Tropospheric Ozone Production about the Spring Equinox". Total column ozone derived from GOES radiances has been found to be within 10 to 20% of TOMS determinations. This derived GOES product could play a useful role in depicting the formation and fragmentation of stratospheric intrusions which cause a dynamically driven fluctuating background in mid-tropospheric ozone on which anthropogenic signals of photochemical production are superimposed. Diurnal features are being studied at CIMSS and Uva. Development of future products in this area is the responsibility of the NESDIS Soundings and Instruments Team; activities will be coordinated with the Ozone Products Oversight Panel.

## 2.3 Practical Implications of GOES Observing Capabilities

### 2.3.1. Imager Products

- \* Higher quality imagery is acquired more frequently. Improved spatial resolution with better signal to noise of GOES imagery combined with routine 15 minute views of the United States allows GOES to provide better coverage for value added users such as TV meteorologists: weather animation (movies) seen by most Americans during the evening newscasts has been greatly improved.
- \* Synchronization with other observations is better. Separate imager and sounder allow for more flexible scan modes. Satellite and Doppler radar data are helping to enhance winter storm forecasting and nowcasting. This program will provide improved weather services for Great Lakes shipping and heavy snow forecast for this important sector of our country.
- \* 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.
- \* Detection of fog is enhanced. During the day, combined visible and 3.9 um imagery has 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.
- \* Surface temperature monitoring is improved. Continuous monitoring of the surface (both land and sea) from geostationary view allows maximum opportunity of cloud free skies. This is important for shipping since SST gradients are related to currents. Enhanced land surface temperature monitoring is important for agricultural applications such as early frost warning.
- \* 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 GOES. This is very important for severe storm (tornado) forecasting: heat and moisture are the fuel for intense thunderstorms.
- \* 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 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 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.
- \* Detection of forest fires and biomass burning is improved. GOES can see 20 to 50 acre fires in remote areas before they are detected from the ground. Assistance with fire weather activities is being pursued.
- \* Polar viewing capability is greatly enhanced. Imagery is now useful well beyond the previous north/south limits. GOES 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.
- \* Depiction of atmospheric changes is best ever in one-minute interval imaging. Optimum ways of combining WSR88D radar and satellite rapid scan data are being explored.

### 2.3.2 Sounder Products

- \* 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 is beginning to show positive forecast model impact. GOES 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.
- \* Hourly supplement of cloud information to ASOS is continued. Accurate delineation of clouds above 12,000 feet is very important to aviation and weather outlooks.
- \* 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.
- \* Moisture determinations for precipitable water monitoring is improved. This capability is being studied to isolate areas where very heavy rains are likely.
- \* Diurnal, seasonal, and annual changes in total ozone content in the atmosphere over the northern hemisphere now is possible. Implications for ozone alerts will be explored.

### 2.3.3 Implications of Improved Products

The improved GOES is beginning to have a positive impact on weather nowcasting and forecasting, which in turn will have positive impact throughout the economy. In addition, the enhanced remote sensing in many spectral bands with continuous surveillance possible from geostationary orbit will enable NOAA to provide other greatly improved services to the nation. In no particular order, the following paragraphs list some examples of services that are beginning to benefit from geostationary multispectral measurements.

- \* In the area of disaster mitigation, hurricane trajectory forecasts are benefiting from better definition of mass and motion fields. Recent improvements in GOES wind field estimations helped the Navy prevent unnecessary fleet movements in 1996; Atlantic fleets were correctly ordered to stay in port for nearby but not threatening hurricanes. More generally, considerable savings are realized for every mile of shoreline (and the associated coastal region) that is not unnecessarily evacuated; a 20% improvement in 72 hour trajectory forecasts is projected to be valued at about \$70M per land falling hurricane.
- \* Improved knowledge of the moisture and thermal field will provide better data for agricultural forecasting and nowcasting. It has been estimated that improvements in three day forecasting of location and timing of rain events (on the order of 500 miles and 12 hours) would enable considerable savings in the reduction of pesticide use over one growing season, as well as mitigate the environmental impact of nitrates leeching into our ground water (important to the United States Department of Agriculture in their program of integrated pest management). Improved forecasts of three day low temperatures would enable more mitigation of crop damage to or loss of temperature sensitive crops (frost warnings). Improved monitoring of ground wetness and temperature for tractability, planting, germination, crop stress, and harvesting, would benefit daily decision making (whether to spray, harvest, plow, etc.).
- \* In the area of transportation by air, ocean, or land there are many weather phenomena that are monitored by geostationary remote sensors. The improved wind, moisture, and temperature information from GOES provides a number of benefits. Better information regarding conditions leading to fog, icing, head or tail winds, and development of severe weather including microbursts en route can be used to make air traffic more economical and safer. Better depiction of ocean currents, low level winds and calm areas, major storms, and hurricanes (locations, intensities, and motions) can benefit ocean transportation in the same way. Information regarding major ice storms, fog, flooding and flash flooding, heavy snowfall, blowing snow, and blowing sand already assist train and truck transportation; improved services should result from the GOES sounder multispectral, high spatial, and high temporal resolution measurements.



\* Power consumption in the United States can be regulated more effectively with real-time assessment of regional and local insolation as well as temperatures. Power services can be maintained more reliably with information for allocation of disaster crews (e.g., for restoration of power) to locations of potential lightning damage. These are associated with thunderstorms which are found in areas of convectively unstable air often delineated by GOES soundings. Local scale forecasts of ice, snow, and flooding will also improve with hourly assimilation of GOES data.

\* General weather announcements affecting public health need improved forecasting and monitoring of surface temperatures in urban and metropolitan areas during heat stress (and sub-zero conditions). GOES sounder data in regional models are demonstrating skill in this application.

The potential impacts of GOES are many and great. There are early indications that the promise of the GOES is beginning to be realized.

### **3. INTEGRATION OF EVALUATION/VALIDATION RESULTS INTO OPERATIONS**

#### **3.1. 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.

#### **3.2. Role of the SPSRB**

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

#### **3.3. 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 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 that has representatives from NESDIS, SAO, NWS, ERL, NASA, DOD, FAA, and the university community (see Appendix B for list of current members); normally, one meeting a year is held.

#### **3.4. 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 SPSRB.

### **3.4.1. National Centers for Environmental Prediction**

The National Center for Environmental Prediction (NCEP) 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 (AWC), Tropical Prediction Center (TPC), Marine Prediction Center, Climate Prediction Center, Environmental Modeling Center (EMC), and the NCEP Central Operations. Active GOES evaluation and utilization projects are 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 TPC (hurricane trajectory forecasts using water vapor and thermal gradient winds); other centers are being approached to participate in the GIMPAP as appropriate.

### **3.4.2. SPC and AWC**

The GOES is significantly enhancing the utility of satellite data in severe weather forecasting. 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 SPC and AWC are working with scientists from NESDIS, CIMSS, and CIRA to explore these new opportunities.

### **3.4.3. TPC**

The TPC 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. TPC forecasters continue to work with NESDIS, EMC, AOML, CIRA, and CIMSS scientists to utilize the improved GOES imagery and to evaluate the impact of the new wind sets on their forecast procedures and their model initializations.

### **3.4.4. EMC**

An extensive effort is underway at EMC to develop the Eta Data Assimilation System (EDAS), which is capable of accepting data on frequent (e.g. 3 hourly) cycles for both level and layer parameters. Thus EMC plans to be in position to exploit the spatial and temporal information available from the GOES products (e.g. cloud-tracked winds, temperature retrievals, layer moisture retrievals, cloud top temperatures). High density cloud and water vapor -tracked winds will be receiving increasing attention. Temperature retrievals are valuable especially over oceanic regions, as they are competitive with those from the TOVS (within 2.5 C rms of radiosondes). Layer moisture retrievals are providing good bounds on several moisture layers for a large area of the western hemisphere. Cloud top temperatures and effective cloud amount indicate cloud type and location. Additionally products such as snow and ice cover, total ozone, and surface temperature 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 is being measured by the EMC in a series of tests where the EDAS (and/or GDAS) is run with and without the GOES information. There is close coordination with assimilation efforts at FSL, CIMSS, and CIRA. These tests have been scheduled with the appropriate Product Oversight Panel (POP) and typically run ten to twenty days. Feedback from these tests is being funneled through the POPs and appropriate product availability is being arranged or the desired product adjustment pursued.

In the July 1995 and May 1996, 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 ETA forecasts. The retrievals of 40 levels of temperature and 21 levels of dew point temperature were converted into three layers of moisture by EMC, 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. The GOES moisture information is being used operationally in the Eta model since October 1997

EMC tested atmospheric motion depicted by cloud motion vectors tracked in GOES images in their global model every six hours. Parallel runs with GOES cloud motion and without showed little difference. Research with GFDL models imply that further study and assimilation efforts are expected to yield positive impacts.

#### **3.4.5. FSL**

The Forecast Systems Laboratory (FSL) (1) evaluates data quality over ISPAN through interaction with the forecast office and the NWS; (2) tests various remapping algorithms to assure equivalent product quality from GOES; and (3) checks GOES 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 determining improvements to the AWIPS data feed and assess its value. FSL has "operational" experience using GOES 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.

#### **3.4.6. NSSL**

The National Severe Storms Laboratory is participating in GOES training and studying the best ways to amalgamate GOES and WSR88D data. Several case studies are being pursued to combine WSR88D depictions of rainfall echoes with very rapid interval imaging from the GOES 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 at NSSL supports this research. Additionally scientists from NSSL are spending extended periods of time at CIMSS and CIRA.

#### **3.4.7 NWS Field Offices**

Over eighty sites acquire digital GOES data on their RAMSDIS (Regional and Mesoscale Meteorology Team 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. Additionally there is a growing Virtual Institute for Satellite Integration and Training (VISIT) program that is providing through the internet GOES data, remote education, and training to NWS forecasters on the utilization and integration of modernized data sources.

CIMSS is working with the nearby Milwaukee/Sullivan and LaCrosse WSFOs in the evaluation of the 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.

### **3.5. Informing the User Community**

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. Selected technical memoranda have been published to assist the user

community. These are summarized in Appendix F, as well as other NWS and NESDIS plans for providing information to the user community. Appendix H outlines the training plan for integrating GOES 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.

Responses from NWS forecasters continue to send a clear message that digital geostationary satellite data have significant operational value and will remain an essential component of the modernized National Weather Service. Recent input from field forecasters provides confirmation of the value of satellite sounder data imager data with high temporal and spatial resolution. During the GOES-10 test forecasters provided numerous examples of how 5- minute interval satellite data improved their ability to detect and forecast a variety of significant weather and weather related events, including: tornadic storms, fog formation and dissipation, precipitation, wave clouds related to turbulence, and fires.

In the coming years the NWS will continue to organize and lead GOES Assessment meetings, update the GOES Requirements Document, collect feedback from participants in the Autoestimator test and document results, and provide NESDIS with NWS priorities for enhancements to satellite derived QPE techniques.

#### **4. EVOLUTION TO IMPROVED PRODUCTS**

While much of the focus for product validation is on GOES-8/9/10, changes to the GOES series are being addressed also. An Instrument Science Team headed by Dr. Paul Menzel has been organized to this end. This team meets periodically to evaluate possible modifications of current instruments and planning of future instruments. Their recommendations are reviewed by OSD and forwarded to the Systems Acquisition Office for action. This section presents some of the present thinking on evolution of products and instruments.

##### **4.1. Evolution of Products**

Products evolve as experience is gained with the GOES 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 current products have been listed in Appendix C. Additional products scheduled for implementation include 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.

The exact process of introducing new products relies on scientific research, a demonstration program for the NWS, coordination with the appropriate POP, approval by the SPSRB, and implementation by the Office of Satellite Data Processing and Distribution (OSDPD). The GIMPAP secures funding for this procedure.

##### **4.2. Participation in Field Experiments**

Evolution of products depends on experience with current 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 using that system. Examples 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. A formal mentor program and feedback mechanism exists within the RAMSDIS experiment that allows for assessment of current products and testing of new products.

Several 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. Four experiments that produced data still under intensive investigation are (1) Verifications of the Origins of Rotation in Tornadoes Experiment (VORTEX), which focused on tornadic storm formation and evolution, (2) the Great Lakes Winter Storm, which focused on nowcasting winter snows in the Great lakes using WSR88D and GOES satellite data, (3) Fronts and Atlantic Storm Tracks Experiment (FASTEX), an international field campaign to study Atlantic Ocean storms, and (4) Northern Pacific Experiment (NORPEX) which studied off shore systems approaching the west coast. 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 present one and three minute imagery and are placed in appropriate NWS field units (with initial focus on the Great Lakes) that work with that imagery, in consultation with CIRA scientists, to explore the benefits of more frequent satellite imagery for nowcasting.

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 new 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.

#### 4.4 New Products

There are a number of current product enhancements and new product developments that are being explored primarily at the cooperative institutes and ARAD. 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: New Products (arranged by POPs)

##### Image, Clouds, and Aerosol

- \* Detection and monitoring of smoke, pollution, volcanic ash and blowing dust.
- \* 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.
- \* Imager principal component images to locate 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.
- \* Severe storm nowcasting with combined satellite and WSR88D data, eventually blended with storm scale models for objective assessment and short term prediction.
- \* Convective potential from satellite mesoscale winds and thermodynamic information that will augment information from other sensors, and will evolve into a combined modernization data product.
- \* Analysis of MCS lifecycle, and eventual nowcasting, from objective IR cloud top analysis along with radar, and eventually mesoscale models.
- \* Storm relative average imagery at various time scales, and as running mean loops, for cyclonic storm system analysis, characterization and forecasting.
- \* Inferring potential for Isentropic Potential Vorticity intrusions into the troposphere and rapid cyclogenesis using of water vapor imagery and model data
- \* Tropical cyclone characterization from a) objective Dvorak technique using IR analysis of current tropical cyclone intensity, in and outside of eye; b) refined surface wind field distribution using satellite cloud motions extrapolated to the surface; 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.

- \* Detection of regions of clear air turbulence in the lee of major mountain ranges using water vapor imagery.
- \* 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.
- \* Daytime 3.9 micron IR product for improved warm/hot area temperature analysis, identification of small cumulus cloud and cloud free thermal boundaries.
- \* Model assessment by comparison with water vapor imagery motion and the location, diagnosis and tracking of vorticity centers using water vapor imagery.

#### Winds

- \* higher density winds with improved tracer selection
- \* 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.
- \* Cloud heights from geometric techniques using shadows and stereographic observations (both geo/geo and geo/polar).

#### Soundings

- \* Gridded and imaged cloud information from the sounder
- \* Refined cloud clearing using model forecasts of surface parameters.
- \* Temperature and moisture soundings independent of a model first guess
- \* Sounder principal component imagery in various combinations to yield information about atmospheric instability, dynamics and cloud properties.

#### Precipitation

- \* Automated precipitation estimates from the imager
- \* Automated precipitation algorithms from combined satellite and WSR88D data which eventually blend with storm scale models for quantitative precipitation amounts and type.
- \* Better screening of rain/no rain events with shortwave and longwave windows

#### Ocean

- \* Sea surface temperature from the GOES merged with AVHRR estimates

#### Surface

- \* Detection of fire temperature and areal coverage with the Automated Biomass Burning Algorithm (ABBA).
- \* Estimation of snow cover.
- \* Estimation of surface albedo
- \* Land Surface Temperature changes as a function of time of day.
- \* Insolation and albedo of clear sky CONUS

## **5. EVOLUTION OF THE GOES INSTRUMENTS**

### **5.1 Near-term Modifications to the GOES Imager**

The imagers on GOES-M/N have been altered to accommodate a CO<sub>2</sub> channel and to increase the spatial resolution of a broadened H<sub>2</sub>O channel. The 13.1 to 13.7 um channel is being substituted for the present 6.5 to 7.0 um channel on the 8 km detector (channel 3) and the 5.8 to 7.3 um channel is being substituted for the present 11.5 to 12.5 um channel on a 4 km detector (channel 5). The addition of the CO<sub>2</sub> 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<sub>2</sub> 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.

For GOES-O all infrared channels will be detected at 4 km resolution. For GOES-P the 11.5 to 12.5 um channel is being restored as a sixth channel at 4 km resolution. 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, to estimate total precipitable water vapor, and to detect dust and volcanic ash. However, at present, there is no operational GOES SST product and estimates of total precipitable water as well as detection of volcanic ash can be done by the sounder.

## **5.2 Evolving to GOES-Q and beyond**

To evolve the GOES measurement capabilities and to address scientific questions that require frequent observations of the atmosphere and surface possible with advanced instrumentation, a suite of instruments is being studied that include an advanced imager, an advanced sounder and the possibility of small, focused research instruments. The science questions involve meso- and regional-scale atmospheric and surface processes and diurnal behavior of clouds, aerosols, constituents, winds, temperature and water vapor. Consequently, the GOES instruments must continuously resolve these phenomena on their most significant space and time scales, typically 30 seconds to 1 hour and every few kilometers, using the radiation windows and molecular bands of the earth's atmosphere. The GOES advanced baseline imager (ABI) is being designed to provide the image frequency and horizontal resolution necessary to resolve dynamical processes and cloud behavior over a hemisphere. The GOES advanced baseline sounder is designed to provide vertical thermodynamic structure with great accuracy in regions of rapid change and information on the quantity of atmospheric trace constituents. The ABI and ABS are being studied with the goal of readiness for launch in the 2005 (early GOES-Q) time frame. Preliminary concepts for an ABI and ABS expand the lifetime expectations to 7 years.

### **5.2.1. ABI observational objectives**

The ABI must be capable of frequent imaging of the full Earth disk and smaller continental and regional areas in 8 or more spectral bands ranging from the near ultraviolet to the far infrared, approximately from 0.4 - 13.5 microns. Spatial resolution of 0.5 km to 4 km depending on wavelength with high signal/noise ratios and precise, accurate and stable calibration is required. Spatial/temporal coverage should provide full disk imagery every 15 minutes or less while simultaneously providing continental and regional coverage at rapid 30 seconds to five minute rates. The specific channels selected will be based on science requirements and heritage from EOS MODIS and the current GOES imager and sounder. The additional information from the new channels, the increased time and space resolutions, and the greater radiometric accuracy will lead to new and/or improved information on the rapid evolution of geophysical parameters including cloud and aerosol characteristics, moisture distributions, surface temperatures and other characteristics of the ocean and land surface (vegetation and ocean color), cloud and water vapor motions and proxies for precipitation. These observations will address science questions related to radiative exchange and balance, transport of energy, moisture and constituents, diurnal variations and short-term changes in the atmosphere and at the surface, and analysis of convective systems and cyclonic storms. These new observations will also lead to advances in the monitoring of significant weather events and other environmental phenomena (fires, etc.).

One design concept of the ABI makes possible full disk images in eight spectral bands in 5 minutes at 2 km infrared and 0.5 km visible resolution. Expansion to more than eight spectral bands remains an option. Clever earth scanning strategies have reduced mirror accelerations dramatically. While the ABI offers improved performance over current GOES in all dimensions, some daunting challenges remain (such as co-registration of spectral bands, encircled energy specifications, and data compression into the available S-band communications bandwidth).

Table: A minimum configuration of an 8 channel ABI with one km vis and 4 km IR resolution. Table indicates Spectral Bands, Resolution and Noise Characteristics, Temperature Range, and Primary Usage.

Ch	Half Bandwidth (um)	Spatial Resolution (urad)	NEDT (deg C)	Range (deg K)	Use
1	.52 +/- .01 to .71 +/- .01 (stay below .72)	28 +/- 15%	1/230	0 - 100%	cloud
2	3.73 +/- .03 to 4.07 +/- .03 (stay below 4.15)	112 +/- 15%	0.2C at 300K	4-335K	cloud, fog, fire
3	13.0 +/- .07 to 13.7 +/- .07 (stay centered at 13.3 +/- .05)	112 +/- 15%	0.7C at 300K	4-320K	cloud height
4	10.2 +/- .1 to 11.2 +/- .1	112 +/- 15%	0.15C at 300K	4-320K	Tcld, Tsfc, winds, fire
5	5.3 +/- .1 to 6.6 +/- .1 (broadened to accommodate 4 km FOV)	112 +/- 15%	0.35C at 230K	4-320K	water vapor, UTH, winds
6	11.5 +/- .1 to 12.7 +/- .07 (keep 12.65 absorption within band)	112 +/- 15%	0.25C at 300K	4-320K	PW, SST
7	6.8 +/- .1 to 7.2 +/- .1 (stay centered at 7.0 +/- .03)	112 +/- 15%	0.25C at 250K	4-320K	mid level H2O winds
8	1.5 +/- .01 to 1.65 +/- .01 (detector limits bandpass to below 1.65)	112 +/- 15%	3/1000	0 - 100%	snow, cld phase

### 5.2.2. ABS observational objectives

The ABS must be capable of frequent sounding of the temperature and moisture structure of the atmosphere with a vertical resolution of 1 km (a significant increase over the 3 km possible with the current GOES Sounder), observing the structure of clouds, and inferring the presence and transport of key atmospheric constituents. The ABS will be able to sound the full disk and smaller continental and regional areas at an hourly rate or faster using the 4-15 micron portion of the spectrum. Measurement of constituents (tropospheric ozone, CO and other trace gases) and their transport will be accomplished over regional areas on an hourly basis with spectral resolution of about  $0.5 \text{ cm}^{-1}$ . The ABS will provide hourly information on temperature and moisture, atmospheric constituents, cloud and aerosol characteristics, surface temperatures and other characteristics of the ocean and land surface, and cloud and water vapor motions. These observations will be important in addressing the science questions related to the structure and dynamics of atmospheric systems, atmospheric chemistry, transport of constituents, and diurnal variations and short-term changes in the atmosphere and at the surface. The observations from the ABS will also provide the operational data required for improved fine-scale modeling and forecasting of significant and severe weather related to convective systems and cyclonic storms.



The ABS design concept follows in the footsteps of previous work using an interferometer, focal plane detector arrays, and on board data processing. An interferometer covers 3.7 to 15.4 microns at 0.625 wavenumber resolution in the longwave; the 15 to 20 centimeter optics promises 10 km resolution; a 16 by 16 detector array provides contiguous coverage of 3000 by 5000 km in 30 minutes. Passive cooling to 75 K enables detector noise to stay below 0.3 K in the longwave; options for active cooling are also being explored. The ability for the ABS to find clear sky holes in cloudy situations remains a major question mark; cloud noise should not exceed instrument noise disproportionately. The ABS represents a significant advance in geostationary sounding capabilities and brings temporal and horizontal and vertical sounding resolutions into balance for the first time ever. Both the ABI and ABS instruments fit into the power, size, weight profiles that can be accommodated on the GOES-Q spacecraft.

### **5.2.3. Challenges**

Data processing is a significant challenge. Currently available A/D converters are adequate for an initial implementation. However, more rapid readout rates would allow for improved S/N due to the ability to retrieve and average multiple scenes. Cutoff wavelengths of longwave photovoltaic focal plane arrays are now approaching 15 microns, the desired longwave cutoff. Space qualified active cryocoolers are currently available that can provide cooling of these focal planes to about 65K as needed. There is also a need for highly linear, long stroke translation devices for moving the sounder mirrors which vary the internal optical path difference. A number of techniques exist now to meet this need. Solid state actuators (i.e., high displacement piezoceramic wafers and piezoceramic linear motors) as well as linear magnetic suspension systems are currently under development that may further improve performance.

### **5.2.4. Other possible additional instruments**

Other instruments with focused objectives are also being studied; these include an ocean color imager, a lightning mapping instrument to improve precipitation estimates and monitor hazardous storms, or a small chemistry/volcanic hazards imager.

### **5.2.5. Design philosophy**

NOAA continues to pursue a philosophy 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-Q focused on the following issues:

- \* assure a continuity of geostationary observing service,
- \* achieve a flexible geostationary system that can accommodate incremental improvements, and
- \* NOAA's satellite system and the rest of the modernized observing service must complement each other.

The long term goals for a GOES include

- \* 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)

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.

#### 5.2.6. Instrument Science Team

The Instrument Science Team 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. Tasks and Cost

Product assurance activities and costs are outlined in this section. More detailed budgets are 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. Activity Areas

	NOAA ARAD/ CRAD	SPC	TPC	NCEP	WSFO	FSL	Univ	Coop CIMSS	Inst CIRA	COMET
Images	X	X	X		X	X		X	X	
Clouds	X				X		X	X		
Soundings	X	X	X	X		X	X	X	X	
Winds	X		X	X			X	X	X	
Precip	X			X	X		X	X		
Other <sup>a</sup>	X			X			X	X		
Training	X				X			X	X	X

<sup>a</sup> This refers to the new product activities in surface products, ocean products, earth radiation budget, and ozone.

## A.2. Cost (in \$1000 units)

FY	Total	NOAA ARAD/ CRAD	NCEP	NSSL	NWS	COMET	FSL	Univ UMD UVA PSU CSU	Coop CIMSS	Inst CIRA
1996	2600	748	60	30	250	250	139	X	605	518
1997	3200	1000	70	35	250	250	146	50	795	604
1998	3440	1219	215	35	150	125	146	90	760	700
1999	3300	1045	280	40	200	X	100	210	795	630
2000	3300	1060	250	40	200	X	100	250	800	600
2001	3400	1140	210	50	150	X	100	350	750	650

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

## A.3. Summary of Tasks

At the most recent review of GIMPAP activities by the TAC in September 1998 and the following activity summary was generated.

### A.3.1 CIRA

Research is planned in

1. nowcasting studies with 5 minute data
2. TC intensity relation with vertical wind shear
3. cloud climatology studies
4. stereo heights for wind vectors
5. fog
6. sounding algorithm development with clustering
7. rainfall algorithm tests
8. AWIPS evaluation (lessons of RAMSDIS)

TAC guidance is to

1. focus on TC genesis and intensity (in collaboration with CIMSS)
2. plan a transitional role for RAMSDIS (as AWIPS emerges)
3. establish special data sets of 5 min GOES and NEXRAD data
4. continue special web based tutorials (e.g. short range fcsting, GOES/radar, nowcasting)
5. assimilate sat rainfall estimates into mesoscale models and study impact
6. pursue principal component analysis of MAS data for spectral info content
7. more collaboration with other efforts on rainfall, cloud mask, fog, volcanic ash

### A.3.2 CIMSS

Research is planned in

1. Eta model impact studies

2. soundings over land (sfc emissivity corrections)
3. wind vector RFF and QI merging as well as use in NCEP models
4. GOES cloud product studies
5. SST diurnal trends and model implications
6. North American Automated Biomass Burning Algorithm development
7. GOES radiance calibration and product validation
8. GOES-L and M checkout

TAC guidance is to

1. explore search box shrinkage in winds algorithm
2. place high priority on soundings over land
3. continue good collaboration with EMC on soundings, GOES cloud products, and winds in Eta
4. help with SST studies
5. expand ABBA beyond fires (e.g. city heat islands, aerosol correction)

### **A.3.3. NSSL**

Research is planned in

1. study severe storm features
2. explore a sire specific rainfall algorithm (with CIMSS)

TAC guidance is that

1. severe weather work should be coordinated with CIRA

### **A.3.4. NWS**

Work will

1. support IR and microwave training module development at COMET
2. continue development of homepage materials in support of training activities
3. support satellite meteorology residence courses

TAC guidance is to

1. coordinate module work with OSD for polar training module
2. coordinate homepage activities with cooperative institutes and ORA scientists

### **A.3.5. NCEP**

NCEP plans to

1. continue efforts to assimilate GOES radiances directly into Eta
2. improve use of high density winds
3. incorporate Satellite Cloud Product into Eta
4. develop physical initialization to help precipitation analysis
5. develop techniques for using land surface products

TAC guidance is to

1. stay aware of transmittance code developments
2. utilize data sets from NORPEX and Hurricane Bonnie for model studies
3. give attention to expanded use of sat radiances over land
4. account for diurnal SST signatures to improve radiance assimilation over water
5. study SCP assimilation in Eta for full GOES product coverage
6. continue physical initialization work
7. strive to publish GOES work in coming year
8. leverage other studies for max benefit

### **A.3.6. FSL**

Work in the coming years will include

1. study sounder PW and imager winds in LAPS
2. tune forward model
3. study thermal adjustment
4. test enhancements for AWIPS

TAC guidance is to

1. emphasize GOES data studies with LAPS/RUC
2. rely on CIRA for AWIPS work
3. rely on ORA for forward model work

### **A.3.7. Surface and Atmospheres Team (SAT)**

Plans are to

1. develop more accurate soil moisture field using GOES insolation
2. deliver product to Eta for testing

TAC guidance is to

1. collaborate closely with EMC
2. keep CIMSS informed of progress to help with their Eta studies

### **A.3.8. FPDT**

Plans are to

1. maintain assistance and backup to IPB for sounding and winds products
3. transition gridded SCP, SST, visible/sounder winds into operations
4. conduct trend analyses of GOES products for science studies

TAC guidance is to

1. establish a product implementation plan for each product
2. emphasize autoestimator, gridded SCP, SST work
3. study product seasonal and annual trends
4. publish more

### **A.3.9. Hydrology Team (HT)**

Research plans are to

1. continue to help with transfer of autoestimator into operations
2. merge polar microwave rain estimates with geo IR estimates
3. study temporal and spatial tradeoffs with G-10 data sets
4. establish skill for non-flash flood systems
5. refine multispectral algorithm

TAC guidance is to

1. try using GMSRA as rain/no rain mask for autoestimator
2. begin microwave work asap
3. continue to assist with op implementation of autoestimator
4. work with CIRA on forward model for rainfall

### **A.3.10. Soundings and Instruments Team (SIT)**

Work is underway to

1. establish leo vis cal algorithm for geo
2. continue GOES vis cal trend study

TAC guidance is to

1. document GOES visible performance

### **A.3.11. ARAD**

General plans are to

1. complete update of GOES Product Services Catalog
2. continue supporting GOES documentation efforts
3. push fog and microburst potential further along into ops

TAC guidance is to

1. study volcanic ash detection w/o split window

### **A.3.12. ORA**

Funds will be used to

1. support ORA fed travel relating to GIMPAP
2. support GOES real time (within 4 days) data access for selected scientists
3. supply seed money for new research projects and ideas
4. participate in GOES evolution working groups (ABI and ABS, AGS,...)

TAC guidance is to

1. support GOES evolution work as much as possible
2. coordinate GOES data access with NCDC as appropriate

### **A.3.13. CIPSU (Penn State University)**

Work has started to

1. test the sensitivity of precipitation estimates in soil hydrology model
2. conduct satellite precipitation data tests in the MM5 model

TAC guidance is to

1. establish links to local forecast office on this work

### **A.3.14. CICS (University of Maryland)**

Research is underway to

1. establish OLR algorithm for GOES sounder
2. study diurnal changes in OLR over NA

TAC guidance is to

1. link GOES with HIRS algorithms
2. publish results of work

### **A.3.15. University of Virginia**

Research will start to

1. remove the temperature dependence in the GOES water vapor channel to derive specific humidity

2. use water vapor radiances to study the formation and fragmentation of stratospheric ozone intrusions into the troposphere

TAC guidance is to

1. connect with CIMSS on water vapor tracing and ozone retrievals

### A.3.16. GHCC (MSFC)

The work for the coming year is to

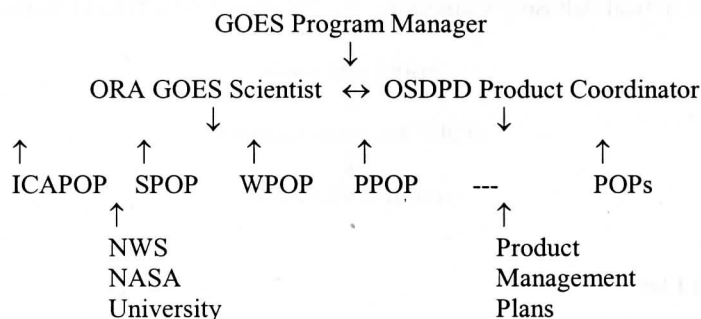
1. study spatial sensitivity in winds algorithm
2. issue final report of 3 year study

TAC guidance is to

1. publish results

## 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.

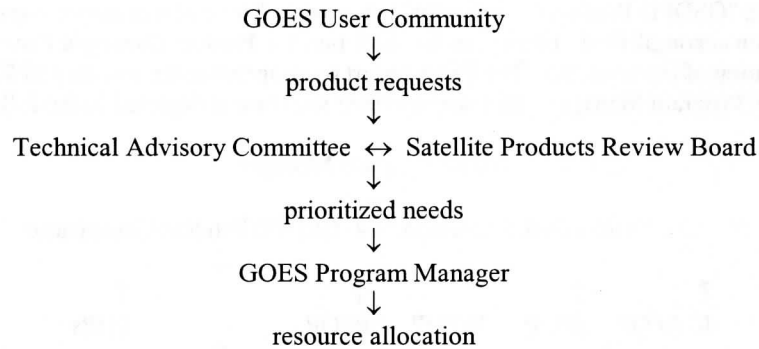
Image, Cloud, Aerosol	G. Ellrod	C. Duda
Soundings	T. Kleespies	E. Brown
Winds	J. Daniels	R. Irving
Precipitation	R. Scofield	J. Paquette
Oceans	B. Pichel	J. Sapper
Ozone	W. Planet	D. Bowman
Surface	D. Tarpley	B. Ramsey
ERB	H. Jacobowitz	I. Guch
Calibration	N. Rao	C. Paris
Navigation	N. Pinkine	E. Harrod
Ocean Color	C. Brown	J. Sapper

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
Jim Gurka	NWS
Alexander MacDonald	ERL
Jamie Hawkins	NOAA
Don Gray	NOAA
Gary Jedlovec	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.



### APPENDIX C. Product List

This list is current as of winter 1999 and will be updated periodically to incorporate new information. Notation is as follows: ph is per hour; pd is per day; CONUS+ is CONUS and adjacent oceans; FD is full disk; PD is partial disk; RISC is using McIDAS-X.

PRODUCT	SENSOR/ SYSTEM	DEVELOPMENT/ IMPLEMENTATION	COVERAGE/ FREQUENCY	USER/ EVALUATOR
<b>Cloud Parameters</b>				
o Cloud Heights (Cloud Top Temp)	Imager/ RISC	Schreiner/(Daniels) Irving	FD/ 1ph	FAA & NWS/ NCEP
o Site specific Cloud Amount (ASOS)	Sounder/ RISC	Schreiner/(Daniels) Irving	CONUS/ 1ph	WSFO & NCDC/ NWS



### Enhanced Data Sets

o GOES Projection (WEFAX)	Imager/ DPSS	Ellrod/ Hughes	FD/NH 8pd/2ph	NWS/ NCEP
o Lambert Conformal (AWIPS)	Imager/ CEMCSS  (Routine, Rapid Scan)	Ellrod	CONUS/ 4,8ph  Hawaii/ 2,4ph  P. Rico/ 2,4ph	NWS & NCDC/ MAR
o Polar Projection (AWIPS)	Imager/ CEMCSS	Tarpley	Alaska/ 2,4ph  NH 2,0ph	WSFO & NCDC/ NWS
o GVAR Data (real time)	Imager/ OGE	Ellrod/ Reynolds	Routine, Rapid Scan	NWS/ NCs

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### Atmospheric Parameters

o Vertical Temperature Profiles (deg K)	Sounder/ RISC	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
o Layer Mean Virtual Temperatures (deg K)	Sounder/ RISC	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
o Vertical Moisture Profiles	Sounder/ RISC	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
o Layer Precipitable Water (mm)	Sounder/ RISC SENSOR/	Schmit/(Daniels) Irving DEVELOPMENT/	CONUS+/ 1ph COVERAGE/	NWS & NCDC/ NCEP USER/
o Total Precipitable Water (mm)	Sounder/ RISC	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
	Imager/ RISC	Schmit/(Daniels) Irving	NH/ 1ph	NWS & NCDC/ SPC
o Channel Brightness Temps (deg K)	Sounder/ RISC	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
	Imager/ RISC	Schmit/(Daniels) Irving	NH/ 1ph	NWS & NCDC/ SPC
o Lifted Index	Sounder/ RISC	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP

	Imager/ RISC	Schmit/( Daniels) Irving	NH/ 1ph	NWS & NCDC/ SPC
o Geopotential Heights (m)	Sounder/ RISC	Schmit/( Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
o Thermal Wind Profiles (m/s)	Sounder/ RISC	Schmit/(Daniels) Carney	CONUS+/ 4pd	NWS & NCDC/ NMC & AOML
o Moisture Analysis (Interactive)	Imager/ RISC	Brown/ Carney	PD/ 4pd	NCEP/ NCEP
o Precipitation Estimates	Imager/ RISC	Vicente/(Daniels)	CONUS+/ 1ph	NWS & NCDC/ NWS & NCEP
o Precipitation Histograms	Imager/ DPSS	Scofield/ Hughes	30N-30S/ 8pd	NCEP/ NCEP

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### Data Bases

o Imager	Imager NCDC	Rutledge	FD/ 2ph	NCDC/ OSDPD
o Sounder	Sounder NCDC	Rutledge	CONUS+/ 1ph	NCDC/ OSDPD
o Vicarious Cal (IR and VIS)	S and I/ DPSS	Weinreb (Rao)/ SOCC		
o Long Term Cal (IR and VIS)	S and I/ PM	Weinreb (Rao)/ SOCC		all/ all

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### Winds

o Cloud Drift (low)	Imager/ NCCF	Hughes/(Daniels) Schreitz	45N-45S/ 4pd	NWS & NCDC/ NCEP
o Cloud Drift (high/low)	Imager/ RISC	Velden/(Daniels) Irving	65N-65S/ 8pd	NWS & NCDC/ NCEP
o Moisture Drift (high/mid)	Imager/ RISC	Velden/(Daniels) Irving	65N-65S/ 8pd	NWS & NCDC/ NCEP
o Moisture Drift (mid/low)	Sounder/ RISC	Velden/(Daniels) Irving	CONUS+/ 8pd	NWS & NCDC/ NCEP
o Visible (low)	Imager/ RISC	Velden/(Daniels) Irving	65N-65S 5pd	NWS & NCDC/ NCEP

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## 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

Forecast Products Development Team (G. Ellrod)	ICAPOP
Product Systems Branch (G. Hughes)	WEFAX
	multispectral products
Soundings and Instruments Team (N. Rao)	insolation
CIRA (D. Hillger)	image quality
(J. Dostalek)	multispectral products
CIMSS (A. Schreiner)	ASOS cloud products
(G. Wade)	multispectral products
Synoptic Analysis Branch (M. Weaks)	user feedback
WSFO Milwaukee/Sullivan (J. Eise)	ASOS cloud evaluation
	multispectral product evaluation
WSFO LaCrosse (D. Baumgart)	ASOS cloud evaluation
	multispectral product evaluation
AWC (F. Mosher)	multispectral product evaluation
FSL (D. Birkenheuer)	LAPS impact studies

### D.2. Sounding

CIMSS (T. Schmit)	POP
	profiles and gradient winds
Forecast Products Development Team (J. Daniels)	derived product images
CIRA (D. Hillger)	software
Synoptic Analysis Branch (M. Weaks)	clustering
WSFO Milwaukee/Sullivan (J. Eise)	user feedback
WSFO LaCrosse (D. Baumgart)	derived product evaluation
AWC (F. Mosher)	derived product evaluation
FSL (D. Birkenheuer)	derived product evaluation
NSSL (B. Rabin)	LAPS impact studies
EMC (J. Derber)	derived product evaluation
	RDAS/GDAS impact tests

### D.3. Winds

Forecast Products Development Team (J. Daniels)	POP, software
Product Systems Branch (G. Hughes)	picture pair winds
CIMSS (C. Velden)	upper level winds
(T. Schreiner)	cloud heights from H2O
CIRA (J. Weaver)	storm relative flow
(C. Vaughn)	geometric cloud heights
Synoptic Analysis Branch (M. Weaks)	user feedback
TPC (M. Mayfield)	wind field evaluations
EMC (G. DiMego)	RDAS/GDAS impact tests
AOML (J. Franklin)	model assimilation

### D.4. Precipitation

Hydrology Team (R. Scofield)	POP
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(G. Vicente)  
Synoptic Analysis Branch (M. Weeks)  
EMC (J. Derber)

autoestimator improvements  
user feedback  
model impact tests

**D.5. Surface**

Surface and Atmosphere Team (D. Tarpley)

POP  
land surface temperature

**D.6. Ocean**

ORAD (B. Pichel)  
(E. Maturi)  
Marine Applications Branch

POP  
SST  
model applications

**D.7. Earth Radiation Budget**

Surface and Atmosphere Team (H. Jacobowitz)

POP

**D.8. Ozone**

Soundings and Instruments Team (W. Planet)

POP

**D.9. Calibration**

Soundings and Instruments Team (M. Weinreb, N. Rao)  
SOCC  
CIMSS (T. Schmit, M. Gunshor)  
CIRA (D. Hillger)

POP  
operational evaluation  
cal intercomparisons  
cal intercomparisons

**D.10. Navigation**

SOCC (K. Kelly, E. Harrod)

POP

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

\* NWS GOES-NEXT Requirements,  
April, 1983

\* 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

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

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

- \* BAMS article “Introducing GOES-I”  
Menzel and Purdom  
May 1994
- \* Proceedings from the Third Workshop on Wind Extraction from Operational  
Meteorological Satellite Data,  
June 10 – 12, 1996
- \* BAMS article on “Fully automated cloud drift winds in NESDIS operations”  
Nieman et al.  
September 1997
- \* Applied Opics article on “Operational Calibration of the Imagers and Sounders  
on the GOES –8 and –9 Satellites”  
Weinreb et al.  
September 1997
- \* EUMETSAT publication of CGMS XXVI on “GOES Temperature and Moisture Soundings in 1997”  
Schmit and Menzel  
6-10 July 1998
- \* EUMETSAT publication of CGMS XXVI on “1997 Report on NOAA/NESDIS  
Automated Cloud-Motion and Water Vapor Drift Vectors”  
Menzel et al.  
6-10 July 1998
- \* BAMS article on “ The operational GOES infrared rainfall estimation technique”  
Vicente et al.  
September 1998
- \* BAMS article on “Application of the GOES-8/9 soundings to weather forecasting and nowcasting”  
Menzel et al.  
October 1998
- \* BAMS article on “An Assessment of GOES-8 Imager Data Quality”  
Ellrod et al.  
November 1998
- \* JAM article on “A non linear physical retrieval algorithm and its application to the GOES-8/9 Sounders”  
Ma et al.  
June 1999

#### **APPENDIX F. Providing Information to the User Community**

The value of GOES 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 1996
- \* American Meteorological Society (AMS) Meeting, January 1997
- \* American Meteorological Society (AMS) Meeting, January 1998

**F.2. Available and Planned Technical Reports**

- \* An Introduction to the GOES I-M Imager and Sounder Instruments and the GVAR Retransmission Format  
NOAA Technical Report NESDIS 33  
October 1987
- \* The GOES I-M System Functional Description  
NOAA Technical Report NESDIS 40  
November 1988
- \* NESDIS Guide to Satellite Products and Services Implementation  
NOAA Technical Memorandum NESDIS 38  
April 1994
- \* GOES-I Data Collection System  
NOAA Technical Memorandum NESDIS 40  
June 1994
- \* WEFAX Users Guide:  
August 1994
- \* GOES Products and Services Catalog  
NOAA Technical Memorandum NESDIS 40  
August 1996
- \* Operational Calibration of the Imagers and Sounder on the GOES -8 and -9 Satellites  
NOAA Technical Memorandum NESDIS 44  
February 1997
- \* GOES Image Quality Analysis System for the NOAA/NESDIS Satellite Operations Control Center  
NOAA Technical Memorandum NESDIS 89  
December 1997
- \* GOES Soundings: New observations for Forecasters  
ORA  
April 1998
- \* GOES I-M Data User's Guide  
NCDC  
June 1998

**F.3. Formalized Training Functions**

- \* Ongoing applied research training at selected WSFOs with RAMSDIS capability
- \* Coordinated field experiments involving Coop Institutes and WSFOs



Lake Effect Snow Experiment  
VORTEX  
FASTEX  
NORPEX

- \* Two week training courses at the COMET  
Nov 97, Dec 97, Feb 98, Apr 98, Jun 98, Mar 99, Apr 99
- \* Computer Based Learning Modules developed by COMET  
Remote Sensing with the New GOES Imager, January 1996  
Using the GOES Sounder, May 1998
- \* CIRA Tutorial on GOES-8 Imager (web)
- \* CIMSS Tutorial on GOES-8 Sounder (web)

#### **F.4. Home Pages**

- \* CIMSS GOES Home Page  
(<http://cimss.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>)
- \* NESDIS ARAD Home Page  
(for precipitation products see <http://orbit-net.nesdis.noaa.gov/arad/ht/ff>)  
(for other products see <http://orbit-net.nesdis.noaa.gov/arad/fpdt>)

#### **APPENDIX G. Operational Schedules**

Operational schedules for GOES-8 in the east covering CONUS and GOES-10 in the west covering PACUS include most elements of the following summary. CONUS indicates continental United States and PACUS indicates Pacific basin and western United States. NOAA is supporting three basic modes of operation: routine, warning, and one minute.

- \* 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

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 is 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 enables 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-10 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-10). 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 using these schedules with GOES-8 in the east and GOES-10 in the west, however, they are subject to change pending review of suggestions for 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-8/10 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**

To fully realize the benefits from the GOES series, operational users are being trained on how to use the data. The NWS in conjunction with NESDIS/ARAD, CIRA, and CIMSS are following a training plan. To accomplish initial GOES training, a series of interactive multi-media Computer Based Learning (CBL) modules have been developed. The modules cover the subjects of analysis and interpretation of imager data and understanding and using sounder products. The modules have been produced by the Cooperative Program for Operational Meteorology, Education and Training (COMET) in Boulder, Colorado with guidance from the CIMSS and CIRA. Every NWS office and a large number of outside users have the computer capabilities to utilize these modules. Other external users such as TV meteorologists, universities, secondary school teachers, international users and the aviation community are also trained by purchasing the CBL modules, videotapes and slide sets, as well as the AMS user workshops that are being provided annually. In addition, the NWS continues to conduct several intensive two week residence GOES courses at COMET (Nov 97, Dec 97, Feb 98, Apr 98, Jun 98, Mar 99, Apr 99) to train the Science and Operations Officer (SOO) and satellite focal points from each office. This provides the trained experts at each NWS office to further lead the efforts on station.

RAMSDIS units at over 80 selected sites are being used as a virtual laboratory to evaluate and validate the GOES 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 focussed on 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

product improvements. As NWS field forecasters get access to digital GOES imager and sounder data on the Advanced Weather Interactive Processing System (AWIPS), they will be able to exploit the advantages of combining high spatial and temporal resolution digital satellite data with radar, profiler and other digital data sources. The RAMSDIS efforts are aimed at reducing risks associated with AWIPS implementation by providing early experience with the GOES data.

In addition, the NWS has created a Virtual Institute for Satellite Integration and Training (VISIT) program. The purpose of the VISIT program is to provide remote education and training to NWS forecasters on the utilization and integration of modernized data sources. VISIT plans to develop the satellite component of this training through close collaboration with experts at the three NOAA Cooperative Institutes to effectively integrate and maximize the use and benefits of satellite imager and sounder data into NWS forecasts and warnings. The resources needed to accomplish this training include hardware, staff and travel expenses. Much of the cost is funded out of the VISIT program.

Table. The focus and expertise of the three institutes participating in VISIT.

Location	CIMMS/NSSL	CIRA/COMET	CIMSS
Primary Database	WSR-88D	Imager	Sounder
Specific Products	Merged GOES/WSR-88D WDSS	Special RAMSDIS products SRSO	GOES Sounder DPI Site-specific Soundings GOES/WSR-88D QPE WV winds
Web Training Resources	Satellite Research at NSSL	RAMSDIS Online Daily Satellite Discussion GOES 3.9 um Tutorial GOES-8 Tutorial COMET Sat Met Pages	GOES Gallery at CIMSS GOES Sounder Tutorial WV Imagery tutorial
Research Associates	6 people	3 people	2 people

## APPENDIX I. Acronyms

ABBA - Automated Biomass Burning Algorithm  
 ABI - Advanced Baseline Imager  
 ABS - Advanced Baseline Sounder  
 ACARS - Aeronautical Radio Incorporated Communications Addressing and Reporting System  
 AIRS - Atmospheric Infrared Sounder  
 AMSU - Advanced Microwave Sounding Unit  
 AOML - Atlantic Oceanographic and Meteorological Laboratory  
 ARAD - Atmospheric Research and Applications Division  
 ASOS - Automated Surface Observing Stations  
 ASPT - Advanced Satellite Products Team (ORA)  
 ATS - Applications Technology Satellites  
 AVHRR - Advanced Very High Resolution Radiometer  
 AWC - Aviation Weather Center  
 AWIPS - Advanced Weather Interactive Processing System  
 CART - Clouds and Radiation Testbed  
 CEMSCS - Central Environmental Satellite Computer System  
 CICS - Cooperative Institute for Climate Studies

CIMMS – Cooperative Institute for Mesoscale Meteorological Studies  
 CIMSS - Cooperative Institute for Meteorological Satellite Studies  
 CIPSU - Cooperative Institute at Pennsylvania State University  
 CIRA - Cooperative Institute for Research in the Atmosphere  
 COMET - Cooperative Program for Operational Meteorology, Education and Training  
 CONUS - Continental United States  
 CRAD – Climate Research and Applications Division  
 CRAS – CIMSS Regional Assimilation System  
 CST - Convective Stratiform Technique  
 DMSP - Defense Military Satellite Program  
 DPI – Derived Product Image  
 EDAS – Eta Data Assimilation System  
 EMC - Environmental Modeling Center  
 EOL - end of life  
 EOS – Earth Observing System  
 ERBS – Earth Radiation Budget Sensor  
 ERL - Environmental Research Laboratory  
 ES - Earth sensor  
 FAA - Federal Aviation Administration  
 FASTEX - Fronts and Atlantic Storm Tracks Experiment  
 FPDT – Forecast Products Development Team (ORA)  
 FSL - Forecast Systems Laboratory of ERL  
 FOV - field of view  
 GCIP – GWEX Continental scale International Project  
 GDAS - Global Data Assimilation System  
 GFDL – Geophysical Fluid Dynamics Laboratory  
 GHCC - Global Hydrology and Climate Center  
 GMS Geostationary Meteorological Satellite (Japan)  
 GOES - Geostationary Operational Environmental Satellite  
 GPS – Global Positioning System  
 GSFC - Goddard Space Flight Center  
 GSS - GOES Sectorizer System  
 GVAR - GOES Variable (data format)  
 GWEX – Global Energy and Water Cycle Experiment  
 HIRS - High resolution Infrared Radiation Sounder  
 HIS - High spectral resolution Interferometer Sounder  
 HT – Hydrology Team (ORA)  
 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  
 MAR - Modernization and Restructuring  
 MIDAS - Multidisciplinary Interactive Display and Analysis System  
 MODIS – Moderate resolution Imaging Spectroradiometer  
 MSFC - Marshall Space Flight Center  
 MTF - modulation transfer function  
 NASA - National Aeronautics and Space Administration  
 NCAR – National Center for Atmospheric Research  
 NCDC - National Climate Data Center  
 NCEP - National Center for Environmental Prediction  
 NEDT - noise equivalent temperature  
 NESDIS - National Environmental Satellite Data and Information Service

NMC - National Meteorological Center  
 NOAA - National Oceanic and Atmospheric Administration  
 NORPEX – Northern Pacific Experiment  
 NOVA - NOAA Operational VAS Assessment  
 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  
 ORAD – Ocean Research and Development Division  
 OSD – Office of Systems Development  
 OSDPD - Office of Satellite Data Processing and Distribution  
 POP - Product Oversight Panel  
 QI - Quality Indicator  
 QPF – Quantitative Precipitation Forecast  
 RAMMT - Regional and Mesoscale Meteorology Team (ORA)  
 RAMSDIS - Regional and Mesoscale Meteorology Branch Advanced Meteorological Satellite  
     Demonstration and Interpretation System  
 RDAS - Regional Data Assimilation System  
 RFF – Recursive Filter Flag  
 RUC – Rapid Update Cycle  
 SAB – Synoptic Analysis Branch (OSDPD)  
 SAO - Systems Acquisition Office  
 SCP – Satellite Cloud Product  
 SAT – Surface and Atmospheres Team (ORA)  
 SIT - Soundings and Instruments Team (ORA)  
 SOCC - Satellite Operations Control Center  
 SOO - Science Operations Officers  
 SPC - Storm Prediction Center  
 SPSRB - Satellite Products and Services Review Board  
 SSMI - Special Sensor Microwave Imager  
 TAC – Technical Advisory Committee  
 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