GOES IMPROVED MEASUREMENTS AND PRODUCTS ASSURANCE PLAN

(GIMPAP)

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Sixth Version
15 December 2001

FOREWORD

The initial draft of this plan was released 9 November 1992; subsequent versions have been released 25 May 1993, 20 December 1994, 26 February 1996, and 28 February 1999. The GIMPAP has been changing as plans and budgets evolve. This sixth version covers the years 2002 through 2004.

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. GOES-9 followed in May 1995, GOES-10 in May 1997, GOES-11 in May 2000, and GOES-12 in July 2001. GOES-8 is serving as the operational GOES-East; GOES-10 is GOES-West. GOES-11 and GOES-12 are in orbit back-ups. These new systems have capabilities that support NOAA programs, both operational and research, in the next decade. In particular, the new GOES has been a key component in the modernization of the National Weather Service (NWS) and its primary mission of providing warnings and forecasts. The forecast by the Director of the National Weather Service in anticipation of the GOES-8 launch , "GOES I-M and other new technologies will have an unprecedented impact on Weather Service operations", has indeed come true (Dr. Friday, GOES I-M Operational Satellite Conference, 1989).

This NOAA GOES Improved Measurements and Products Assurance Plan (GIMPAP) plans and organizes the efforts to assure the viability of GOES 8 through GOES-P 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. Measurements and products 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 are realized.

This plan details the efforts over the next several 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 GIMPAP

* Identifies the necessary linkages between NESDIS and the NOAA organizational elements using GOES data, products, and services.

* Defines GOES products as well as the testing and evaluation necessary to ensure their 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 satellite schedules that support NWS operations (including advanced NWP models), national research projects, and integration with other components of the Global Observing System.

* Presents a product management structure utilizing the NESDIS Product Oversight Panels

* Identifies an oversight mechanism through 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 continue to be focused on measurement and product validation, improved utilization, accommodation of the spectral band changes occurring in the GOES-12 Imager, transfer of algorithm (new or improved) into operations, and user tele-training. The GIMPAP 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 improved measurement and product assurance activities resides with the "GOES Program Manager", assisted by a "GOES Scientist" and a "Product Coordinator". The Product Oversight Panels (POP) oversee the maintenance and evolution of the products and report to the SPSRB (Satellite Products and Systems 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 8-12 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 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) and the National Weather Service (NWS). The purpose of the plan is to: (1) assure that the GOES 8-12 through P 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 8-12 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 8-12 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 mostly completed. 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, are automatically displayed on the Advanced Weather Interactive Processing System (AWIPS) in order to improve the flow of information to the forecaster. New products have been developed that rely on information from the partnership of these high technologies that will accompany NWS modernization. The GOES Improved Measurements and Products Assurance Plans (GIMPAP) coordinates the 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 have been placed at NWS National Centers and field offices that 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 GIMPAP 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 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 occurs. Section 4 discusses the evolution to improved products and instruments. Appendix A indicates the government and university laboratories plus the resources that are 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 details a training plan for the NWS and other users. An acronym list occupies Appendix H.

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, ERL, and 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 activities outlined in this plan consist of data collection, technique development, product validation, and user familiarization in the first tier; further technique development, new product generation, and demonstration periods for the NWS in the second tier; and evaluation and incorporation of new techniques in the third tier.

2.1. Characterizing and Validating Instrument Performance

GOES 8-12 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 inter-calibrations 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 8-12 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. Unfortunately the visible spectral response extends beyond 0.72 microns, making vegetation and clouds less distinct (this is being addressed for subsequent GOES Imagers and ABI). 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 8-12 Imager, Meteosat-7, and GMS-5 performance (wrt GOES specified noise values)

Band	Bit Depth	Resolution	Noise
	G8-12/ M7/G5	G12/G8-11/M7/ G5	G12(spec)/G11/G10/G9/G8/M7/G5
Visible			counts
.65 um	10 / 8 / 6	1 / 1 / 2.5 / 1.25 km	3 (7) / 3 / 3 / 3 / 3 / 1 / 1
IR Windows			(deg C at 300 K)
3.9 um	10 / X / X	4 / 4 / X / X km	.21 (1.4) / .13 / .11 /.08 / .16 / X / X
10.7 um	10 / 8 / 8	4 / 4 / 5 / 5 km .	.10 (.35) / .07 / .09 / 07 / .12 / .18 / .11
12.0 um	10 / X / 8	X / 4 / X / 5 km	X (.35)/ .18 / .19 / .14 / .20 / X / .13
Water Vapor			(deg C at 230 K)
6.7 um	10 / 8 / 8	4 / 8 / 5 / 5 km	.16 (1.0) / .20 / .14 / .15 / .27 / .35 / .40
Carbon Dioxide			(deg C at 230 K)
13.3 um	10 / X / X	8 / X / X / X km	.18 (.35) / X / X / X / X / X/ X

The GOES 8-12 imagers are close to meeting their pointing requirements over the continental United States (CONUS) sector; various motion compensations are working well. The GOES 8-12 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 8-12 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; GOES 11-12 continued this good longwave channel performance. 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 8-12 Sounder

Wavelength (um)	Ch	NEDT G-10 (290K)	NEDR G-8 (mW/m2/ster/cm-1)	G-9	G-10	G-11	G-12	(spec)
Longwave								
14.7	1	0.41	1.76	1.16	0.71	0.67	0.75	(0.66)
14.4	2	0.31	1.21	0.80	0.51	0.51	0.64	(0.58)
14.1	3	0.24	0.98	0.56	0.41	0.37	0.45	(0.54)
13.9	4	0.24	0.74	0.46	0.41	0.36	0.39	(0.45)
13.4	5	0.21	0.68	0.45	0.36	0.34	0.35	(0.44)
12.7	6	0.09	0.32	0.19	0.16	0.17	0.14	(0.25)
12.0	7	0.06	0.20	0.13	0.09	0.11	0.11	(0.16)
Midwave								
11.0	8	0.08	0.13	0.09	0.12	0.14	0.12	(0.16)
9.7	9	0.09	0.16	0.11	0.10	0.13	0.14	(0.33)
7.4	10	0.10	0.08	0.08	0.07	0.09	0.10	(0.16)
7.0	11	0.07	0.07	0.05	0.04	0.06	0.06	(0.12)
6.5	12	0.17	0.11	0.09	0.07	0.11	0.11	(0.15)
Shortwave								
4.57	13	0.07	0.012	0.008	0.007	0.006	0.006	(0.013)
4.52	14	0.05	0.010	0.007	0.005	0.007	0.006	(0.013)
4.45	15	0.05	0.009	0.006	0.005	0.006	0.006	(0.013)
4.13	16	0.06	0.004	0.003	0.003	0.003	0.003	(0.008)
3.98	17	0.06	0.004	0.003	0.002	0.003	0.002	(0.008)
3.7	18	0.06	0.002	0.001	0.001	0.001	0.001	(0.004)

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.

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

GOES-8 Sounder Band	Brightness Temperature Difference (K)
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

Radiances have been 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. CIMSS has been intercalibrating five geostationary satellites (GOES-8, -10, METEOSAT-5, -7, GMS-5) with a single polar-orbiting satellite (NOAA-14 HIRS and AVHRR) on a routine, automated basis for the past two years using temporally and spatially co-located measurements. Large data sets of intercomparisons of both 11-µm infrared window (IRW) and 6.7-µm water vapor (WV) channels have been accumulated (results for all five geostationary satellites covering the time period from January 2000 to July 2001 are shown in the Table). The mean is the average of all cases for the indicated satellite and a negative sign indicates the measurements from the polar-orbiting instrument (HIRS or AVHRR) are warmer than those from the geostationary instrument. All five geostationary instruments on average are measuring colder temperatures than HIRS and AVHRR in the IRW channel; they measure warmer temperatures on average than HIRS in the WV channel. The standard deviation is the deviation about the mean. In the IRW channel the standard deviations for ΔT_{AVHRR} are lower than they are for ΔT_{HIRS}; the standard deviations for the WV channel comparisons are smaller than those in the IRW channel for ΔT_{HIRS}.

Table: January 2000 to July 2001 IRW (top) and WV (bottom) comparison of geostationary satellites and NOAA-14 HIRS and AVHRR.

Delta (geo – leo)		GOES-8 IRW	GOES-10 IRW	MET-5 IRW	MET-7 IRW	GMS-5 IRW
Number of Comparisons	ΔT_{HIRS}	29	227	240	291	119
	ΔT_{AVHRR}	29	227	240	291	119
Mean	ΔT_{HIRS}	-0.6 K	-0.3 K	-1.0 K	-1.1 K	-0.8 K
	ΔT_{AVHRR}	-0.4 K	-0.0 K	-0.3 K	-0.8 K	-0.6 K
Standard Deviation	ΔT_{HIRS}	0.8 K	1.2 K	1.35 K	0.8 K	1.2 K
	ΔT_{AVHRR}	0.3 K	0.4 K	0.6 K	0.7 K	0.7 K

Delta (geo – leo)		GOES-8 WV	GOES-10 WV	MET-5 WV	MET-7 WV	GMS-5 WV
Number of Comparisons	ΔT_{HIRS}	148	272	236	175	139
Mean	ΔT_{HIRS}	1.4 K	2.2 K	4.2 K	3.9 K	1.5 K
Standard Deviation	ΔT_{HIRS}	0.5 K	0.7 K	1.2 K	0.5 K	0.9 K

Additionally, 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, have been 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. GOES-8 visible cal trends are shown in the Figure; a degradation of 4.7 % per year is found. For GOES-9 this was 2 % per year before termination of operations. GOES-10 is under study.

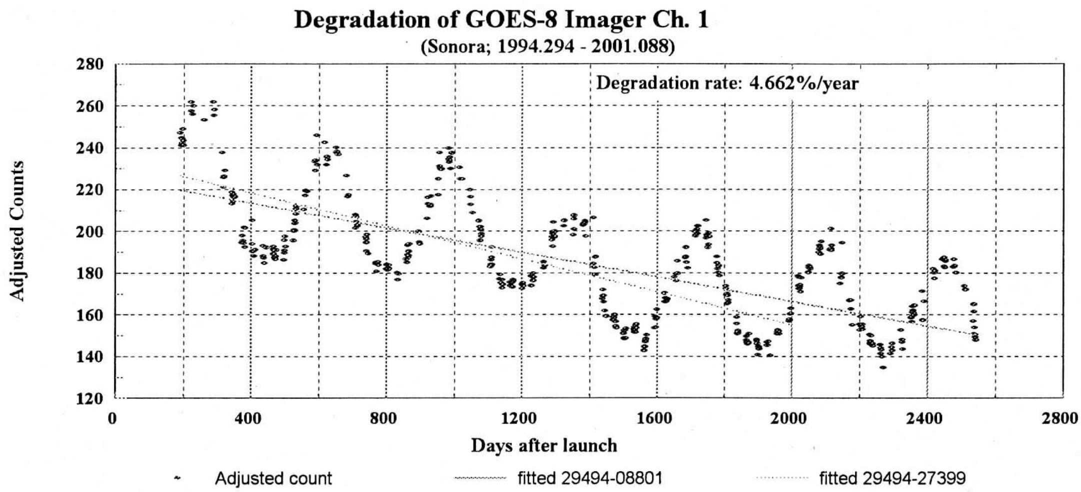


Figure: GOES-8 visible channel performance trend as a function of days after launch. Adjustments are made for the changes of the earth sun distance seasonally.

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 evaluated 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 with the Image, Cloud, and Aerosol POP.

The GOES imager five channels for GOES 8-11 are: (1) 0.62 um (vis) used for imaging clouds, snow and ice, and land features; (2) 3.9 um (shortwave infrared window) used for identifying fog/stratus, cloud vs snow, fires/volcanoes, and sea surface temperature (SST) determination; (3) 6.7 um (water vapor channel) used for synoptic analysis, upper tropospheric humidity, and identifying convection; (4) 10.7 um (longwave infrared window) used for cloud tracking, locating cloud tops, and SST determination; and, (5) 12.0 um (split window) used primarily for low level moisture identification and SST determination. GOES –12 adds (6) 13.3 um (carbon dioxide channel) used for cloud tracer height assignment while removing the 12.0 um split window cannel.

Proven capabilities of GOES - Imager include
* rapid scan imaging within one and five minutes
* more details in imagery (4 km IR resolution, oversampled visible, 2X better signal-to-noise, bit depth)
* greatly enhanced low light visible capability (10 bit visible data)
* ability to detect clouds changes and cloud movement rapidly
* timely fog and low cloud detection at night (continuous 3.9 um imaging)
* immediate detection of sub km fires and resultant aerosol transport (3.9 um and visible)
* detection of blowing dust
* diurnal land surface temperature excursions

* capability to identify clouds with aircraft icing potential (good 3.9 and 10.7 um signal and resolution)
* daytime detection of snow cover in the absence of clouds (3.9 and vis)
* high cloud detection for safer aircraft in air refueling
* best water vapor (6.7 um) imagery ever (factor of ten improvement enables identification of mesoscale disturbances in synoptic scale features)
* better cloud-drift and water vapor motion winds (50% more vectors with reduced slow bias in upper levels)
* better monitoring of heavy rainfall (good 10.7 um resolution and signal)
* enhanced timely depiction of changes in atmospheric stability (better delineation of moisture gradients high and low in derived product images using 6.7, 10.7, and 12.0 um)

Since June 2000, the GOES scanning schedules provide the capability to routinely use higher frequency interval imagery in the operational product derivation at NOAA/NESDIS. GOES 15-minute CONUS and PACUS image sectors are available routinely for product generation for GOES-8 and GOES-10, respectively. In addition, more frequent 7.5-minute imagery rapid scan imagery is automatically utilized when the GOES imager is placed in rapid scan mode. Use of this higher frequency interval imagery has resulted in significant improvements in derived products, especially in vector coverage and more uniform winds. The Northern Hemispheric image sectors, which are scanned every 30 minutes, are used to generate products outside the CONUS, PACUS, and RISOP domains in order to achieve full Northern Hemispheric coverage. The Southern Hemispheric image sectors, which are scanned every 30 minutes, are used to achieve coverage in the Southern Hemisphere. These image sectors are illustrated in the Figure.

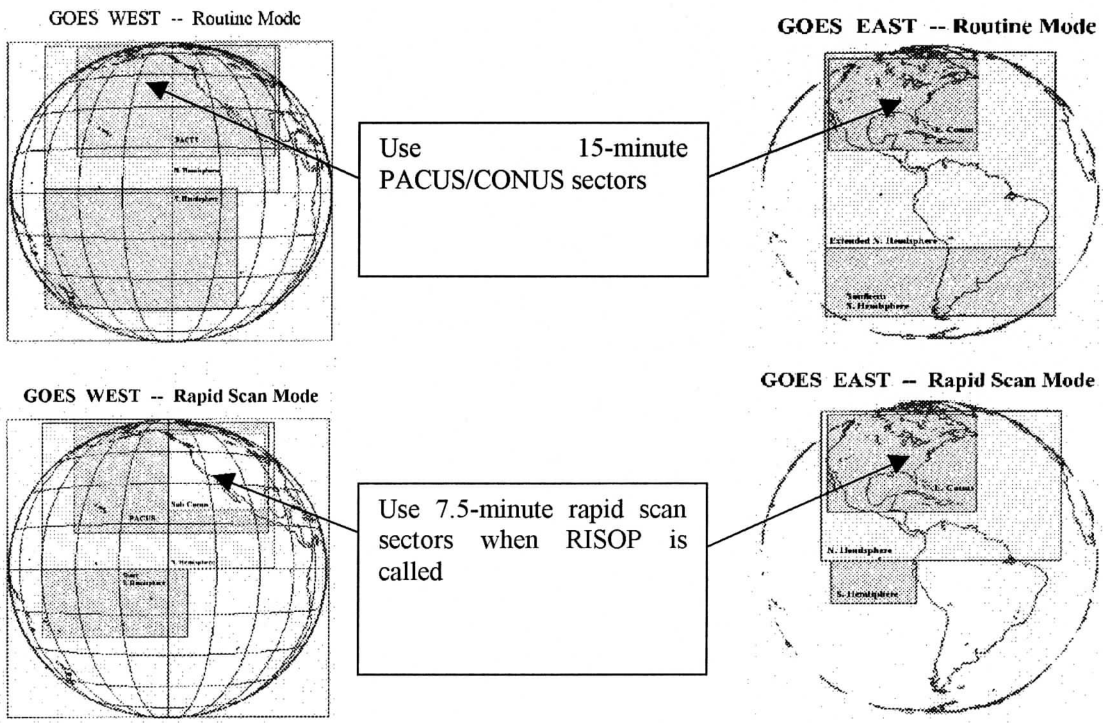


Figure: GOES-East and -West Image Sectors. Use of CONUS, PACUS, and RISOP sectors offer benefits to data processing.

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, (6) evaluating the utility of the different spectral bands for volcanic ash detection; and 7) investigation of innovative training methods.

The University of Virginia (UVa) 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 CO2 sensitive spectral band brightness temperatures are being subtracted from upper tropospheric H2O 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, has developed 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).

CIMSS has developed and validated a GOES cloud product through comparison with ground observations with NWS participation. The satellite cloud information complements the ASOS cloud information that is limited to altitudes below 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. This product is migrating from the Sounder to the Imager with the introduction of CO2 channel on GOES-12.

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; they continue to work 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 have been participating in Lake Effect Snow investigations centered on the Great Lakes in the Midwest; these offices are coordinating evaluation activities with CIRA. The Western Region WSFOs are providing valuable evaluations of Derived Image Products and special image enhancements.

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. Activities in this area are coordinated with the Soundings POP. 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.

Proven capabilities of the GOES – Sounder include
* very good temperature and moisture soundings (better rms comparison with radiosondes)
* sounding coverage in the vicinity of clouds greatly improved (better resolution of sounding areas)
* moisture information significant for forecast models (delineation of changes in data sparse areas / times)
* hourly high cloud information for ASOS supplement
* better depiction of boundary layer thermodynamics (low atmospheric temperature/moisture with shortwave bands)
* higher quality thermal gradient winds over oceans (for hurricane trajectory models)
* greatly enhanced depiction of changes in atmospheric stability
* continuous monitoring of ozone indicating stratospheric – tropospheric exchanges

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.

The NOAA/NESDIS operational GOES-8/10 soundings continue to be produced every hour at 50 km resolution in clear skies (research retrievals are being run at 30 km resolution). Derived Product Images (DPI) of Total column Precipitable Water vapor (TPW) and atmospheric stability are being used by the NWS forecast offices. GOES definition of three layers of moisture is used operationally by regional forecast; impact of cloud properties at single field of view (FOV) resolution (approximately 10 km) is being investigated. The effects of surface emissivity in profile retrievals from infrared multispectral radiances are being studied. GOES-11 performance has been checked out; GOES-12 check out occured late summer/fall 2001.

Operational production of GOES-8/10 soundings continues every hour over North America and the nearby oceans. For the last several years, GOES retrievals at both CIMSS and NESDIS (designated as OPS) have been produced using a nonlinear physical retrieval algorithm (Ma et al. 1999). This algorithm uses GOES Sounder cloud-free radiances that have been averaged N x N FOVs to adjust first guess vertical profiles of temperature and moisture. At CIMSS, the averaging is done within a 3 X 3 matrix of FOVs, while the NESDIS operational retrievals are produced using a 5 X 5 FOV matrix. Since the nominal horizontal resolution of a GOES Sounder FOV is 10km, the nominal dimensions of the CIMSS and NESDIS retrievals are approximately 30 X 30 and 50 X 50 km, respectively.

The Table below shows statistics for both the CIMSS and OPS GOES retrievals versus radiosonde (collocated within 0.1 degrees latitude/longitude). The GOES-8 TPW tends to be drier than the collocated RAOB TPW. The standard deviation (SD) is reduced for all retrievals compared to the first guess. The 12Z retrieval SD values tend to be larger than their 00Z counterparts. GOES-10 TPW bias and SD values are reduced compared to GOES-8 data; also average GOES-10 TPW are significantly smaller than for GOES-8. However, the retrieved GOES-10 TPW is closer to the collocated radiosonde TPW than the guess when compared to GOES-8. Finally, the correlation coefficients (CC) are also smaller for GOES-10 than for GOES-8.

The Figure below shows a time series of GOES-8 00UTC and 12UTC combined TPW retrieval versus radiosonde bias for the CIMSS and OPS retrievals. Note the overwhelming tendency for negative biases, in agreement with the Table. Also, the biases for both the CIMSS and OPS retrievals are maximized, in terms of largest dry bias versus the radiosondes, during the warmest and most moist summer months, and minimized during the cooler/dryer months. The same warm/moist and cool/dry seasonal tendencies also exist for GOES-10 (not shown). Furthermore, comparing the CIMSS and OPS biases to each other, one can see an interesting shift that occurred about July 2000. Prior to that time, the CIMSS biases tended to be closer to zero than the OPS retrievals, while after that point the OPS retrieval biases were closer to 0.

DATASET	PERIOD	BIAS	SD	AVG GUESS / RET TPW	AVG RAOB TPW	CC	N
00Z CIMSS G-8 TPW guess	1/98-6/01	-0.62	3.15	16.25	16.88	0.959	2260
00Z CIMSS G-8 TPW retrieval	1/98-6/01	-0.64	3.04	16.23	16.88	0.961	2260
12Z CIMSS G-8 TPW guess	1/98-6/01	-1.10	3.39	16.51	17.61	0.957	1870
12Z CIMSS G-8 TPW retrieval	1/98-6/01	-0.89	3.22	16.72	17.61	0.961	1870
00Z OPS G-8 TPW guess	1/98-6/01	-0.23	3.33	17.68	17.91	0.956	750
00Z OPS G-8 TPW retrieval	1/98-6/01	-0.62	3.05	17.29	17.91	0.963	750
12Z OPS G-8 TPW guess	1/98-6/01	-0.61	3.38	17.65	18.26	0.963	679
12Z OPS G-8 TPW retrieval	1/98-6/01	-1.11	3.29	17.15	18.26	0.965	679
00Z CIMSS G-10 TPW guess	1/99-6/01	-0.40	2.62	10.00	10.40	0.906	630
00Z CIMSS G-10 TPW retrieval	1/99-6/01	-0.35	2.05	10.05	10.40	0.944	630
12Z CIMSS G-10 TPW guess	1/99-6/01	-0.86	2.73	11.06	11.92	0.925	442
12Z CIMSS G-10 TPW retrieval	1/99-6/01	-0.41	2.56	11.51	11.92	0.936	442
00Z OPS G-10 TPW guess	1/99-6/01	-0.11	2.59	12.17	12.29	0.928	143
00Z OPS G-10 TPW retrieval	1/99-6/01	0.12	2.46	12.41	12.29	0.935	143
12Z OPS G-10 TPW guess	1/99-6/01	-0.76	2.66	10.72	11.48	0.900	170
12Z OPS G-10 TPW retrieval	1/99-6/01	-0.49	2.46	10.99	11.48	0.914	170

Table: Retrieval versus radiosonde statistics. Collocation distance is approximately 0.1 degrees latitude/longitude. BIAS, SD and AVG values are in mm.

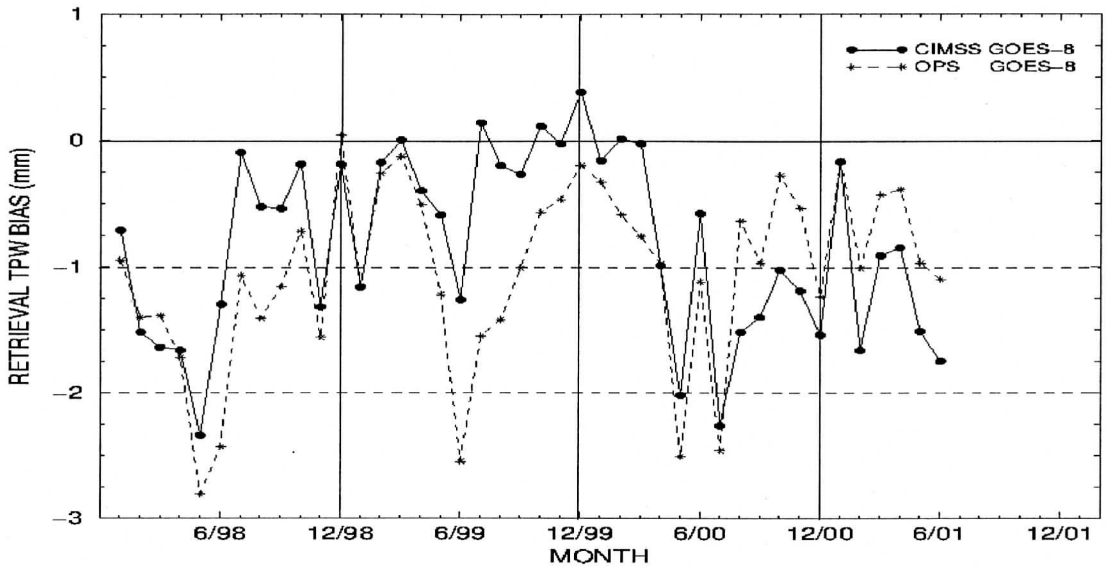


Figure: GOES-8 CIMSS and OPS monthly TPW bias for Jan 1998 through Jun 2001.

GOES-11 soundings were established during checkout in August 2000. The GOES-11 sounder signal to noise performance was improved over previous sounders and GOES-11 moisture retrievals improved over GOES-8. For 50 radiosonde/retrieval comparisons, the rms TPW was 5.3 mm for GOES-11, 6.1 mm for GOES-8, and 6.7 mm for the model first guess. See http://cimss.ssec.wisc.edu/goes/g11_report/index.html for more information.

Validation with respect to measurements from the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site continues. GOES retrievals are compared with Microwave Radiometer (MWR) moisture determinations. Figure below shows a one-day comparison of TPW on 6 Aug 2000 from the GOES-11 checkout. While the first guess from time-interpolated Eta forecasts is relatively flat throughout the period, the GOES retrieval algorithm produces nearly the same water vapor tendency patterns as measured by the MWR. GOES follows the water vapor fluctuations between a local maximum at approximately 900 UTC to a local minimum at 1700 UTC; the temporally and spatially coarse radiosonde network does not capture those changes. Overall, GOES demonstrates skill in resolving the mesoscale water vapor fluctuations on this day. Early indications are that the GOES-11 sounder is less noisy and has less striping than the operational GOES-8 sounder.

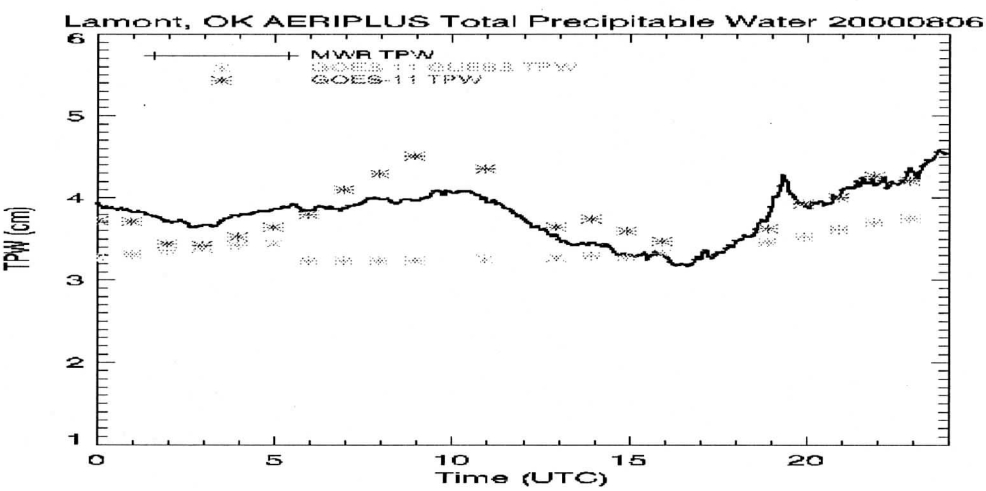


Figure: Microwave radiometer (solid line), model first guess (blue stars), and GOES-11 physical retrieval (red stars) TPW comparisons near Lamont, OK on 6 Aug 2000. First-guess trace is flat but GOES-11 retrievals show ability to capture the diurnal trend and range of moisture variation.

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) 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 CART site in Oklahoma; GOES temperature and moisture information is being compared to ground based interferometer, GPS, microwave radiometer, and class sondes routinely.

Soundings and Derived Product Images (DPI) continue to be made available to NWS Forecast Offices in realtime, assisting the forecasters with their short-term forecast responsibilities. Forecasters have found that the sounder profiles and DPIs are making significant positive impacts to their forecasts of location and timing of severe weather (such as thunderstorms). From 19 July through 30 August 1999, the NWS Office of Meteorology conducted daily assessments of the operational value of the GOES-8 and GOES-10 sounder products. Thirty-seven NWS forecast offices, four national centers, and the NESDIS Satellite Analysis Branch participated in the evaluation, providing a total of 638 responses. Forecasters used the sounder products to heighten their awareness of the potential of a wide variety of weather events, including severe thunderstorms, monsoon precipitation, and flash floods. Their responses showed that in over 79% of all active weather situations, the use of GOES sounder products led to the issuance of improved forecasts. In the words of a forecaster in Minneapolis, MN on 9 and 10 August 1999 who stated:

> "The Sounder DPI helped a lot anticipating convective development over southern MN this evening. I looked through the DPI's over a few hours and saw a definite decreasing trend in the CINH (Convective Inhibition) from 19-21Z. It was only a matter of time before the convection fired into southern MN. Impressive CAPE values (3500-4500J/KG) and LI's -10 to -12 pointed to the possible severity of the convection. We received many reports of funnels/brief tornado touchdowns across south central MN as the convection went through. We were about ready to give up on any serious development...it was quite late (after 8pm CDT) before it developed. These products overlayed on surface maps/satellite/radar displays on AWIPS would be invaluable to the mesoscale forecaster."

New displays have been developed to assist the forecaster in diagnosing atmospheric trends; these include plotting GOES minus first-guess values over the matching DPI (to highlight impact areas), including primary representative parameters and levels with respect to stability (850mb T, Td; 500mb T), and adding three layers of moisture DPI (compared to only total values previously). The Figure below shows an example from 8 Aug 2000.

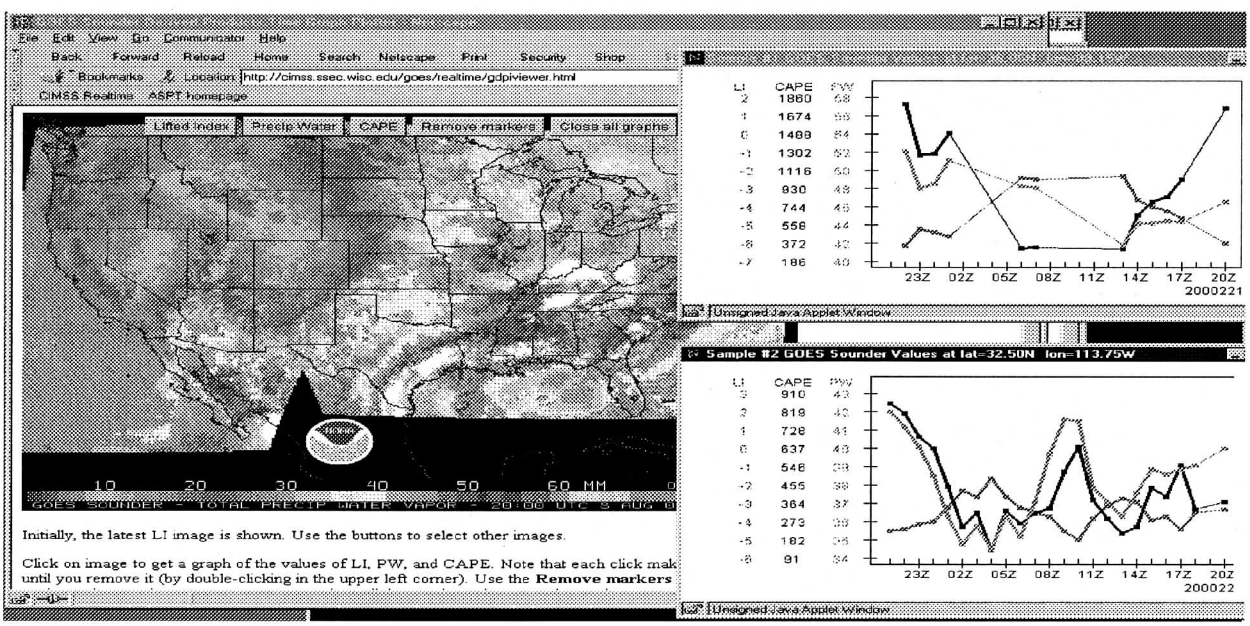


Figure: GOES Sounder determinations of atmospheric trends inferred from hourly Convective Available Potential Energy (CAPE), Lifted Index (LI) and Total Precipitable Water Vapor (TPW) on 8 Aug 2000. The top trend shows afternoon destabilization in far western Kentucky and the bottom trend shows monsoon moisture re-surging in southwestern Arizona. The Derived Product Image of TPW is for 2000 UTC.

Real-time examples of both retrieved moisture and stability information as well as cloud top pressures continue to be displayed on the CIMSS web site at http://cimss.ssec.wisc.edu. Another site with real-time GOES sounder products supported by the NOAA/NESDIS Forecast Products Development Team is http://orbit-net.nesdis.noaa.gov/goes/.

Single FOV (SFOV) retrievals are being investigated as the signal-to-noise ratio of the GOES sounders continues to improve with the May 2000 launch of GOES-11and the July 2001 launch of GOES-12. To minimize striping, spatial averaging (3x3 or 5x5 FOV) was a necessity for GOES-8. Striping is not seen in GOES-11 sounder SFOV total precipitable water retrievals. SFOV retrievals can achieve coverage not possible with coarser resolution retrievals. Additionally, values compare well with higher resolution MODIS (MODerate resolution Imaging Spectro-radiometer) data. The Figure below presents an example comparison of GOES-11 and MODIS TPW from 24 Jul 2000.

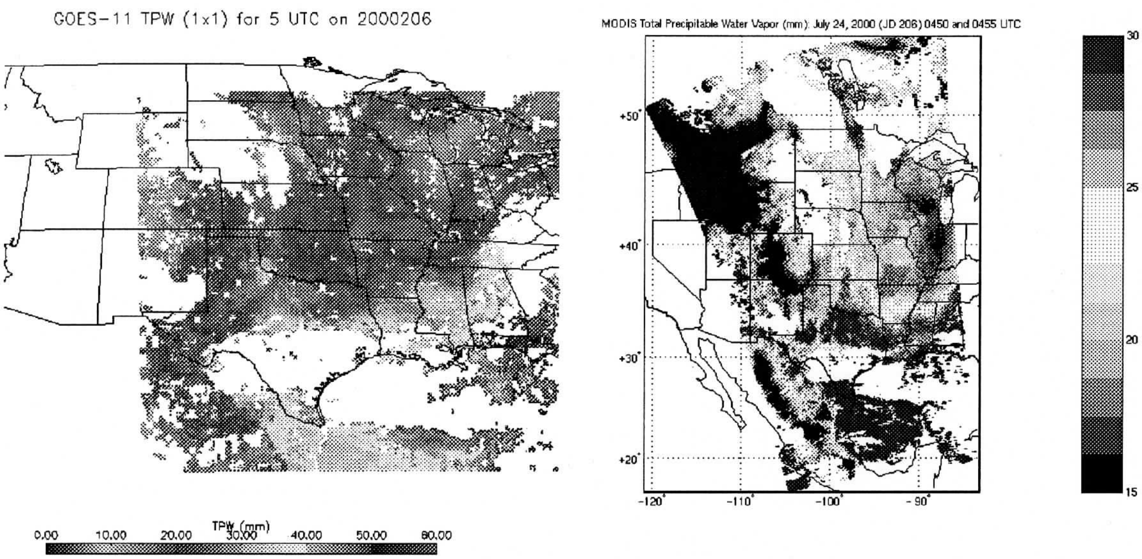


Figure: (left) GOES-11 Sounder SFOV 10 km retrievals of TPW (mm) at 0500 UTC on 24 Jul 2000 and (right) MODIS 5 km retrievals of TPW (mm) at 455 UTC on 24 Jul 2000.

In an attempt to reduce the dependence of the GOES soundings on a model first guess, a regression relationship between the Sounder radiances and colocated radiosonde determinations of atmospheric temperature and moisture has been established for use as an alternate first guess. Work continues in this area at CIMSS.

To improve the accuracy of vertical temperature-moisture profiles retrieved from GOES sounder IR measurements, the surface emissivity (SE) must be accounted for in the solution of the inverse problem. A model accounting for SE and an algorithm of solution have been developed. The solution includes SE, the surface temperature, and the temperature-moisture profile. Results over land have shown that accounting for SE positively effects the solution. It is found that over land the SW band is noticeably cooler (~2 [K]) than in LW band; over water the reverse is true. On average land SE in the SW are noticeably less than in the LW. Water SE variations within the spectrum are small. SE reduction decreases the contribution of the warm surface into the outgoing radiance and increases the contribution of the cooler atmosphere. Figure below shows the SW SE retrieved from GOES Sounder radiance measurements at 10 UTC for May through June 2000. The SW SE ranges from 0.86 to 0.96 and exhibits strong spatial variability. The associated atmospheric temperature and moisture retrievals (not shown) exhibit more spatial continuity (and hence more thermo-dynamical consistency) than retrievals that do not account for non-blackbody surface emissivity variations.

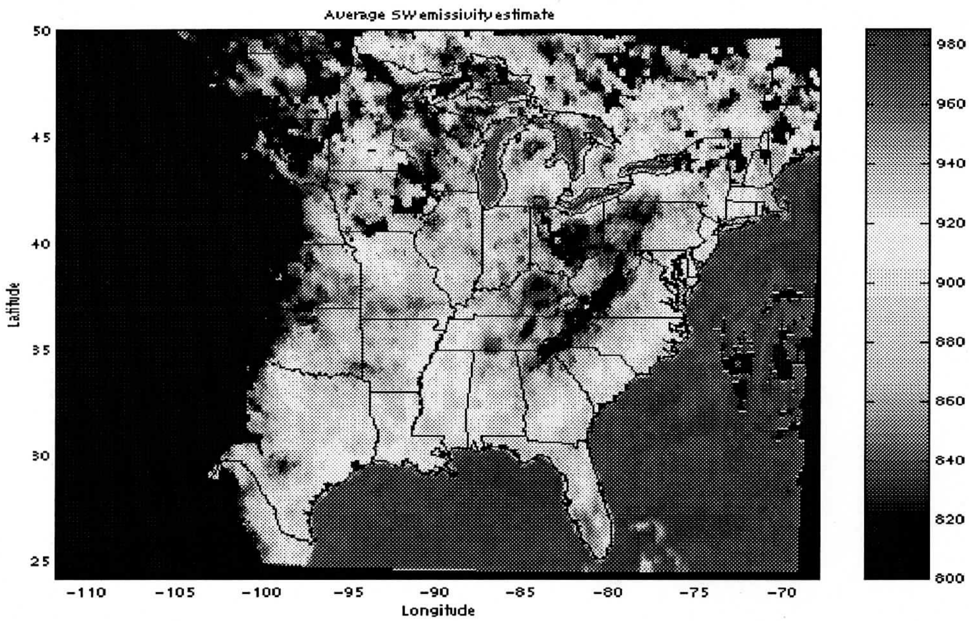


Figure: Average of GOES-8 estimates of 3.8-4.2 micron (SW) surface emissivity (SE) for 10 UTC in May through June 2000. Dark blue areas indicate missing estimates due to persistent cloud cover.

During the winter of 1999/2000, an improved cloud detection subroutine was tested. Several shortwave channels have been incorporated to help distinguish snow from cloud. The algorithm is based on the decreasing reflectivity of the shortwave channels with increasing wavelength. Positive results have lead to plans for operational implementation in the coming year.

Investigation of the GOES ability to depict boundary layer properties is just starting. Techniques using the shortwave channels on GOES are being studied to improve 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

The current operational wind products being generated at NOAA/NESDIS are shown in the Table below where the frequency at which each product is produced, together with the GOES image sector used, and image interval are presented.

Table: NOAA/NESDIS Operational Wind Products

Wind Product	Frequency (hrs)	Image Sector(s)	Image Interval (min)
IR Cloud Drift	3	Extended NH; SH	30
Water Vapor	3	Extended NH; SH	30
Vis Cloud Drift	3	RISOP	7.5
	3	PACUS/CONUS	15
	3	Extended NH; SH	30
Sounder 7.0 WV	3,6	CONUS/Tropical	60
Sounder 7.4 WV	3,6	CONUS/Tropical	60

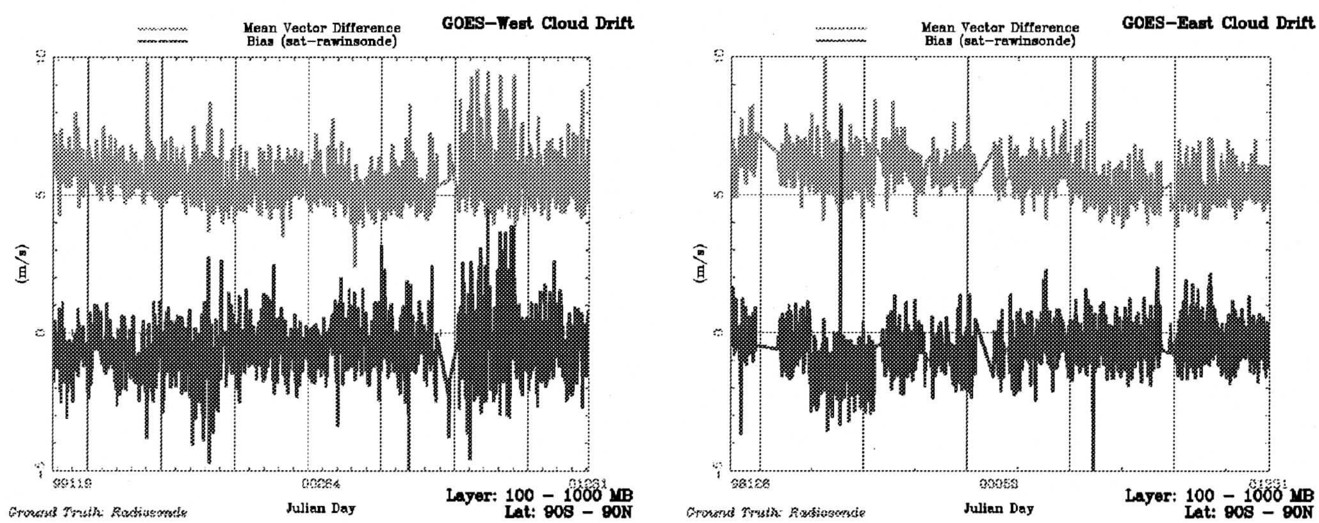
The newest operational wind products include the visible cloud drift and GOES sounder water vapor motion winds. The visible cloud-drift wind products are generated routinely for GOES-8 and -10 every three hours during daylight hours over the Northern and Southern Hemisphere. The GOES sounder water vapor winds are generated every three hours over the Continental United States (CONUS) and every six hours over the adjacent oceanic regions.

The winds are calculated by a three-step objective procedure that is 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 H2O intercept method (GOES-12 enables a CO2 slicing height assignment). 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 um from the imager, 7.0 and 7.4 um from the sounder) are derived by the same methods used with IRW and visible 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.

NOAA/NESDIS, together with CIMSS, is continuing to improve the operational wind product suite which include high density visible and IRW cloud-drift and water vapor motion winds. All of the NOAA/NESDIS wind products continue to be encoded into the unified BUFR template. NOAA/NESDIS processing strategies utilize available 15-minute and 7.5-minute image loops for the derivation of visible cloud-drift winds. The quality of the wind products continues to look good. Figure below shows the GOES cloud drift winds compared with radiosonde observations for the past 2 years; the root mean square is around 6 m/s and the bias is less than 1 m/s.

Figure: Statistics (bias and root mean square) of GOES-W (left) and GOES-E (right) cloud drift winds compared with radiosonde observations for May 1999 through August 2001.



The recent Workshops on Wind Extraction from Operational Meteorological Satellite Data (Sep 1991; Dec 1993; June 1996, Oct 1998, Feb 2000) 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 Oct 1998 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).

There are several active research areas. One involves improving the clear-air water vapor winds. (a) Specifically, WV feature tracking can be significantly improved by increasing the time interval between WV imagery from 30 minutes to 60 minutes. Increased vector coverage at middle levels (400-700mb) of the atmosphere are observed when using 60 minute interval imagery. When these winds are compared to radiosondes, improvements of 2-3 m/s in the mean vector difference are observed. (b) Another area of research involves assessing the impact of using the middle image in an image triplet to perform target selection and height assignment for all wind product types. Wind vectors are computed forward and backward in time and averaged in this approach. This approach opens up additional opportunities for quality control involving vector consistency checks. (c) Other planned operational implementations include production of the EUMETSAT Quality Indicator (QI). CIMSS has transferred code to NESDIS FPDT for operational implementation. This code includes the Quality Indicator (QI) module (Holmlund et al. 2000), and the capability to process winds from other geostationary satellites (GMS, Meteosat). (d) The further exploration of winds from five minute interval GOES images (Velden, 2000) will include an exploitation of a special GOES-10 scanning mode data collected during the PACJET field experiment in early 2001, and in subsequent PACJET experiments. Testing is underway with the recently-launched GOES-11 satellite, which includes a science checkout period with 5-minute imaging; (e) An examination of nighttime 3.9 micron greater capability for detecting coherent low-level cloud tracers is proving fruitful; transition to routine production is proceeding. (f) Analysis of water vapor wind height assignments (Rao et al. 2000) still is receiving attention; assignment adjusted by weighting function peaks is being studied. (g) Model impact studies continue (Soden et al. 2000). (h) Application of the wind fields to hurricane analyses is improving (Dunion et al. 2000).

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

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 included the following capabilities: (1) infrared window rain rate curve, (2) supplemented with rain mask based on available atmospheric total precipitable water vapor and 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 were gathered and published in Vicente et al (1998).

Since then the autoestimator has been adapted to use fifteen minute image loops, visible as well as the other infrared radiances, and ancillary data (such as WSR-88D, rain gauges, and microwave radiances from SSM/I and AMSU). A version of the Auto-Estimator called the Hydro-Estimator (H-E) has been recommended for operational implementation (AWIPS, etc) by the NWS/Office of Hydrologic Development and the NESDIS Satellite Analysis Branch (SAB). Validation shows that the H-E generally has a lower bias than the other satellite algorithms. H-E uses: a statistical screening procedure to help delineate rain from non-raining pixels and splits the PWRH moisture correction factor into two components: PW and RH; this splitting of the PW and RH appears to better handle more stratiform precipitation. A key advantage of the H-E over the A-E is that the H-E performs almost as well without the use of radar (A-E is dependent on radar to insure reliable rainfall estimates, especially with large area cold top systems).

For lighter rainfall detection a GOES Multispectral Rain Algorithm (GMSRA) has the following characteristics:

* IR, 6.7um, 3.9 um, VIS channels for rain ID-IR at night (1/2 hour estimates; 40 mm/hr highest rain rate)
* probability of rain and mean rain rate for IR temperature classes
* calibrated against radar
* moisture and dynamic adjustments as in Auto-Estimator
* does well in warm rain; underestimates intense rain events
* some regional calibrations have been incorporated

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. 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 μm channel and the effective radius of cloud particles near their tops is derived from the reflected solar irradiance at 3.9 μm. Negative Brightness Temperature Difference (BTD) IR-WV (11 μm - 6.7 μm), which corresponds well with rainfall areas for very deep convective cores, 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 μm) 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. GMSRA has been found to compare 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. Recent GMSRA work is evaluating

* nighttime screening techniques for nocturnal warm rain (difference between 3.9 and 10.7 um)
* IR split window screening of thick non raining clouds for both daytime and nighttime

Blended GOES infrared and POES microwave algorithms (Turk, MIRRA - microwave infrared rain rate algorithm, and SCaMPR - Self-calibrating multivariate precipitation retrieval) are under testing. Studies of a neural network/expert system for GOES instantaneous rain rates are also planned.

2.2.7. Surface Products

Research in several product areas, such as insolation, land surface temperature, and fire detection have lead to routine production. GOES estimates of insolation and clear sky land surface temperature have been developed in support of a Land Data Assimilation System (LDAS). 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 a Land Data Assimilation System (LDAS) started testing, validating a method for estimating soil moisture fields over the Eta domain. 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 are determined from measurements, and the remaining variables from the Eta model. The shortwave radiation (insolation) are 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 comparison of the derived surface temperature with that observed from satellites. Validation and diagnostic analysis of the land surface schemes make use of surface temperature retrieved from the GOES imager.

The infrared window bands (4 and 11 um) on the GOES-8 imager have proven to be very useful for fire detection. For GOES-8, the minimal detectable fire burning at 450 K is .002 km^2. For the biomass burning season in South America fires as small as .01 km^2 have been detected. The GOES-8 imager is also 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 phenomenom, in North America they are often initiated by lightning in cloudy conditions; hence the fire detection algorithms are 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) has been exploring a number of potential GOES products. CICS has been 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.

Errors characteristics of GOES Outgoing Longwave Radiation (OLR) were analyzed using the Clouds and Earth's Radiation Energy System (CERES) observations. The comparisons are based on over 28,000 data collected in July 1998 and April 2000 over the continental United States. The July data correspond to observations from GOES-8 and 9 and the CERES instrument on board the Tropical Rainfall Measurement Mission (TRMM). The April data correspond to GOES-8 and 10, and two CERES instruments on board the Terra satellite. The comparisons are for instantaneous, homogeneous scenes of 1°x1° boxes. Comparisons of GOES with collocated TRMM and Terra CERES OLR show instantaneous RMS agreement to within about 7 Wm^{-2} for day and/or night homogeneous scenes. The GOES technique explained over 91% and 96% of the variance of CERES observations for both night and day, and for both land and ocean scenes for July 1998 and April 2000, respectively.

A multi-spectral outgoing longwave radiation (OLR) estimation technique was applied to GOES Sounder data to study the diurnal cycle of OLR. OLR data collected from several regional areas over the continental United States and adjacent oceans during July 1998 are analyzed to determine diurnal variations for clear-sky and all-sky conditions. It is found that the desert regions exhibit a diurnal range that can reach up to about 70 Wm^{-2} while the vegetated areas and ocean regions exhibit much lower diurnal range. The results show that the monthly diurnal variation of the different regions can be approximated with a sine-like function, with the desert sites exhibiting a more perfect sine curve. It is also found that the rms errors associated with sparse data such as those of polar orbiting satellites depend on sampling time and interval.

Research at CICS is focussed on (a) developing a methodology for estimating OLR, LC, and SLR, (b) discovering the inherent problems from comparison with other data (CERES, HIRS and ARM), and (c) exploring features of atmospheric energetics. Work in the next two years will be

* comparing GOES, HIRS and CERES data products for different spatial and temporal analyses,
* comparing SLR and LC products with ARM and other in situ data where appropriate, and
* developing an implementation plan for transfer of the OLR, LC and SLR algorithms to NESDIS operations.

This follows upon similar activities carried out with the now operational HIRS algorithms.

Investigations are also 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. 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 this product plays a major role). 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.

* Precipitable water vapor 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 has had a positive impact on weather nowcasting and forecasting. In addition, the enhanced remote sensing in many spectral bands with continuous surveillance possible from geostationary orbit 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 the 36 hour trajectory forecasts is projected to be valued at about $20M and could also provide increased lead time for hurricane preparations.

* 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, NWS, OAR, 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 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 AWIPS is proceeding. 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

EMC is developing the tools 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). The Eta Data Assimilation System (EDAS) is capable of accepting data on frequent (e.g. 3 hourly) cycles for both level and layer parameters. High density cloud and water vapor -tracked winds is receiving 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. Radiances measured by GOES imager and sounder are by inspected for use in the Global Data Assimilation System (GDAS), 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.

00-hr sensitivities and 24-hr ETA forecast impacts (FI) of remotely sensed satellite data, including three layer clear air GOES precipitable water (GOESPW) and GOES infrared cloud drift wind (GOESCD) and water vapor cloud top wind (GOESWV), were conducted for three 11-day periods in 13-23 December 1998, 10-20 April 1999, and 13-23 July 1999. Sensitivity and FI statistics in temperature, u-component of the wind, and relative humidity were evaluated. The 24-hr FI results indicate that all of the data types provide some positive impact. GOESCD is a consistent contributor during all three time periods. GOESPW had the most positive FI during summer in terms of relative humidity, but their importance was reduced during winter. GOESWV had the smallest impact, with the overall contribution being just slightly positive. While the positive FIs are termed modest for all data types, it is important to note that very few negative FIs were observed, even when examining individual time periods. During both the assimilation and forecast, most data types impact the fields they do not observe as much as the ones they do. For example, precipitable water data affect the u-component of the wind, while GOESCD winds affect the relative humidity.

Several future studies are planned. First, a similar sensitivity and FI study of data in global models that would remove boundary condition problems. Second, research on the error characteristics of data types and forward models could mitigate the conservative assignment of satellite observation errors used operationally. A more complete understanding of how to utilize existing and future data types is required if modeling improvements related to the available data are to be realized.

EMC continues to test assimilation of 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 show little difference. The impact of the GOES motion vectors is being studied in other forecast models; the best approaches toward assimilation remain under evaluation. Hurricane trajectory forecasting is an example of promising positive impact. A study was conducted at the Geophysical Fluid Dynamics Laboratory (GFDL). High density, multi-spectral GOES-8 winds (from three water vapor, the infrared window, and the visible bands) were assimilated into the GFDL hurricane forecast model for over 100 cases from Atlantic tropical cyclone situations in 1996-1998. The winds were directly assimilated using optimal interpolation and vertical blending schemes. GOES data reduced the 24-72 hr hurricane track forecast errors by ~10% on average.

Table. Recent forecast results using GOES high-density winds in the Geophysical Fluid Dynamics Laboratory (GFDL) hurricane model from selected Atlantic Tropical Cyclones in 1996-1998 (this includes 10 storms and 103 cases). Forecast trajectory errors are estimated for 12, 24, 36 and 72 hours. Improvements are indicated in percentage of the mean forecast error as well as the percentage of the forecasts.

forecast out to	mean fcst error	fcst error improvement with GOES winds	% of fcsts improved with GOES winds
12 hr	70 km	4.5 %	50
24 hr	125 km	10 %	60
36 hr	160 km	12.5 %	60
72 hr	350 km	9 %	60

The impressive GFDL control runs (relative to other models) without the GOES data were improved even more with the GOES winds (Soden et al., 1999). A similar improvement in performance by the Navy's NOGAPS model with high density GOES winds has been noted in prior hurricane studies (Velden et al., 1998; Goerss et al., 1998). Further research is planned with NCEP to achieve optimum operational utilization of the high density GOES winds.

3.4.5. NWS Field Offices

GOES data and products are appearing on the AWIPS. Also the Virtual Institute for Satellite Integration and Training (VISIT) program is providing 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. OAR Participation

3.5.1. FSL

The Forecast Systems Laboratory (FSL) (1) helps to guide GOES products into AWIPS, (2) explores use of GOES data in the LAPS (Local Area Prediction System) surface temperature, cloud, and moisture analyses, and (3) supports field experiments with GOES products. 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.

3.5.2. 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.

3.6. 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. Forecasters continue to request AWIPS improvements that will allow them to more fully exploit GOES imager and sounder data (as was available to them on experimental RAMSDIS systems).

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

4. EVOLUTION TO IMPROVED PRODUCTS

While much of the focus for product validation is on GOES-8-12, 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. 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. The GOES schedules (described in section 2.2.3) 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).

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. VISITview, 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 VISITview 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. Experiments that produced data still under intensive investigation are (1) the Great Lakes Winter Storm, which focused on nowcasting winter snows in the Great lakes using WSR88D and GOES satellite data, (2) Northern Pacific Experiment (NORPEX) which studied off shore systems approaching the west coast, (3) Pacific Jets (PACJET) which studied jets and moisture strucuture in the Pacific near the U.S. west coast, (4). Convective and Mesoscale Experiment (CAMEX-4) orchestrated observations with one to 15 minute interval satellite imagery (RSO and SRSO) of a large number of hurricanes and tropical storms while they were being observed with NOAA, U.S. Air Force Reserve, and NASA hurricane hunter and research aircraft, and (5) The International H2O Project (IHOP_2002), a field experiment scheduled to take place over the Southern Great Plains (SGP) of the United States from 13 May to 30 June 2002, has the chief aim of improved characterization of the four-dimensional (4-D) distribution of water vapor and its application to understanding and prediction of convection.

Experience from the above mentioned experiments has provided, and is expected to continue to provide, a wealth of information that allows for development of meaningful new products and in the planning for future geostationary satellites. 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.

4.3. New and Enhanced 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; they are prioritized by the POPs .
Table: New and/or Enhanced 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

* GOES-12 winds with CO2 and H2O heights
* GOES High Density winds in BUFR format (AWIPS)
* Explore using middle image targeting for all wind types and use of 60-min WV imagery for WV winds (R. Irving,J. Daniels, W. Bresky)
* POES scatterometer winds (BUFR) for AWIPS
* Operational testing/implementation of the unified EUMETSAT/NESDIS QI; include QI parameter in BUFR records
* Algorithm development/validation of 3.9um cloud-drift winds
* GWINDEX-II rapid scan winds
* Analyze/validate water vapor winds by (a)determing optimal tracking interval for WV targets (60 min) and (b) analyzing water vapor height assignments
* Explore derivation of polar winds from POES and/or MODIS image loops
* Collaborate with NWP scientists to optimize the assimilation of satellite winds

Soundings

* OPS should improve and disseminate the DPI products.
  - The sounder products should be disseminated via AWIPS.
  - The cloud products should be made available in BUFR format.
  - Incorporate the fix for low/marine clouds
  These data are needed for numerical model initializations and if they are to used by the Eta model, need to be implemented by ops. (G. Krasowski, Holland, Kayser, Daniels)
* GOES-12 combined imager and sounder. The GOES-12 satellite has a new imager channel. The format of the (combined imager and sounder) transmittance files must be modified. These modifications must migrate from CIMSS to FPDT, and beginning with the program that generates weighting functions from FPDT to OPS. (Schmit et al., Daniels, Holland)
* GOES-11 Post-Launch Test Report (check-out and product generation). Submit this as a NOAA technical report. During the GOES-11 post launch test check-out, products have been generated and compared to other products. (Schmit et al., Daniels, Holland)
* GOES-12 Post-Launch Test Report (check-out and product generation). Submit this as a NOAA technical report.
* OPS use new transmittance model (PLOD/PFASST) for retrievals and produce retrievals at a higher spatial resolution. Currently ops is using a 5x5 fov averaging scheme. The ultimate goal is for single fov data to be produced and transferred. This switch must be coordinated with NCEP, beginning with a test data set. (Holland, Daniels, Derber)
* Continue to support the transfer the sounder data and products (retrievals and images) into AWIPS. (Carney, Holland, Daniels)
* Improve the surface emissivity within the retrieval algorithm. Improve the surface emissivity within the retrieval algorithm. (Schmit, Kleespies)
* Incorporate a snow detection algorithm into the cloud detection. (Schmit et al.)
* Improve the first guess (increase horizontal, vertical and temporal resolutions, etc) (Daniels, Schmit et al.)
* Investigate/optimize the use of the Discrepancy Principle into the routine retrieval production at CIMSS.
* Investigate combining data from other satellites with the GOES data.
* Investigate and test numerical model-independent retrievals. (Schmit et al.)
* Investigate using OPTRAN as the forward model. This would unify the forward model used in the retrieval generation and assimilation. This may save resources and result in quicker advances. (CIMSS)

Precipitation

* Continue improving versions of the Auto/Hydro-Estimator (A-E & H-E, respectively)
  - test GMSRA rain discrimination methods as a front end for the A-E & H-E (since it uses all 5 channels)
  - test GOES sounding derived PW/RH adjustments to the H-E and A-E
  - develop a rain burst factor (to account for the very heavy rainfall that occurs in the first hour of a developing MCS)
  - locate heavy rainfall in the upwind portion of the anvil
* Continue improvements and collaboration concerning the GMSRA
  - identify warm top rainfall
  - improve screening for thick non raining clouds
  - improve regional calibrations
  - continue collaboration with the NWS/OHD on the application of satellite rainfall estimates to river forecasting (initially working with WGRFC)
* Continue improvements and collaboration on combined microwave and GOES precipitation methodologies
  - continue to test and evaluate Turk algorithm continue to test, evaluate, and improve Kuligowski Combined Microwave/GOES Algorithm, called SCaMPR (Self-Calibrating Real-Time GOES Rainfall Algorithm) for Short-Tem Rainfall Estimate
* Continue and expand the NESDIS QPE verification program
  - continue validating/assessing our family algorithms (with respect to season, region, and type of system) for determining which algorithm (s) or combination of algorithms should be implemented into operations.
  - Expand systematic validation process with six satellite precipitation algorithms (A-E, H-E with

radar, H-E without radar, GMSRA, GMSRA with nighttime screen, GOES/microwave blend) over five RFC
- test basin-scale rainfall from the GOES auto-estimator for flash flood monitoring and prediction of stream flow using a hydrological model. Verification in Oklahoma/north Texas, the Carolinas, and in Arizona will be started at NSSL
* Continue collaboration on Artificial Neural Network Algorithms
* Work with NCEP/EMC (DiMego and Ying Lin) to use GMSRA (H-E) for helping to initialize the ETA model over water
* 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
* Incorporate surface reflection into skin temperature algorithm

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 INSTURMENTS

5.1. Near-term Modifications to the GOES Imager

The imagers on GOES-12/N have been altered to accommodate a C02 channel and to increase the spatial resolution of a broadened H2O 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 CO2 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 CO2 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/P the CO2 channel will have 4 km resolution.

5.2. Evolving to GOES-R 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 2008 (early GOES-R) time frame. Preliminary concepts for an ABI and ABS expand the lifetime expectations to 7 years.

5.2.1. ABI observational objectives

To keep pace with the growing need for GOES data and products, NOAA is evolving its geostationary sensor capabilities. The Advanced Baseline Imager (ABI) will be the next generation geostationary imager on GOES-R, beginning in 2010. As with the current GOES Imager, this instrument will be used for a wide range of both qualitative and quantitative applications. The ABI will include a number of improvements over the existing imager besides the additional bands. The ABI will improve the spatial coverage from nominally 4 to 2 km for the infrared bands, as well as almost a five-fold increase of the coverage rate (Gurka and Dittberner 2001). This imager, as currently envisioned, will have a minimum of eight spectral bands and a maximum of twelve spectral bands. The minimum eight bands are similar to the five bands on the current GOES-8/11 Imagers (Menzel and Purdom 1994), plus a snow/cloud-discriminating 1.6 μm band, a mid-tropospheric 7.0 μm water vapor band, and a 13.3 μm band useful for determining cloud heights and amounts. This carbon dioxide-sensitive band is similar to that on the GOES-M and beyond series of Imagers (Schmit et al. 2001). The ABI bands were selected after considering NWS requirements, existing bands on the GOES Imagers and Sounders, bands on other future geostationary satellites, and bands on current and future polar-orbiting satellites. For example, the next generation METEOSAT (METEOrological SATellite) Second Generation (MSG), to be launched in 2002, will have 12 channels, including two water vapor channels centered at 6.2 and 7.3 μm (Schmetz et al. 1998). Proposed ABI bands include:

* 0.64 μm visible band used for: daytime cloud imaging; snow and ice cover; detection of severe weather onset detection; low-level cloud drift winds; fog; smoke; volcanic ash, hurricane analysis; and winter storm analysis.
* 1.6 μm band used for: cloud/snow/ice discrimination; total cloud cover; aviation weather analyses for cloud-top phase (Hutchison 1999); and detecting smoke from low-burn-rate fires.
* shortwave IR window (3.9 μm) band used for: fog (Ellrod et al. 1998) and low-cloud discrimination at night; fire identification (Prins et al., 1998); volcanic eruption and ash detection; and daytime reflectivity for snow/ice.
* 6.15 μm and 7.0 μm bands used for upper and mid-tropospheric water vapor tracking; jet stream identification (Weldon et al., 1991); hurricane track forecasting; mid-latitude storm forecasting; severe weather analysis and for estimating upper level moisture (Soden et al., 1993; Moody et al., 1999).
* longwave infrared window (11.2 μm) band used for: day/night cloud analyses for general forecasting and broadcasting applications; precipitation estimates (Vicente et al., 1998); severe weather analyses; cloud drift winds (Velden et al. 1998a); hurricane strength (Velden et al. 1998b) and track analyses; cloud top heights; volcanic ash detection (Prata 1989); fog detection (in multi-band products); winter storms; and cloud phase/particle size estimates (in multi-band products).
* 12.3 μm band used for: nearly continuous cloud monitoring for numerous applications; low-level moisture determinations; volcanic ash identification detection (Davies and Rose 1998); Sea Surface Temperature measurements (Wu et al. 1999) and cloud particle size (in multi-band products).
* 13.3 μm band used for: cloud top height assignments for cloud-drift winds; cloud products for ASOS supplement (Schreiner et al. 1993; Wylie and Menzel 1999); tropopause delineation; and estimating cloud opacity.
* 8.5 μm band, in conjunction with the 11.2 μm band, used for: detection of volcanic dust cloud containing sulfuric acid aerosols (Realmuto et al. 1997; Baran et al. 1993; Ackerman and Strabala 1994). In addition, the 8.5 μm band can be combined with the 11.2 and 12.3 μm bands to derive cloud phase (Strabala et al. 1994).
* 10.35 μm band used to derive: low-level moisture; cloud particle size; and surface properties. Chung et al. (2000) showed how the 10 - 11 μm region is important for determining particle sizes of ice-clouds.
* 0.86 μm used to detect aerosols and vegetation. Characterizing aerosols and their optical properties is essential for improving a number of satellite products, for example land and sea surface temperatures. This band may enable localized vegetation stress monitoring, fire danger monitoring, and albedo retrieval. Other applications include suspended sediment detection (Aquirre-Gomez, 2000).
* 1.38 μm used to detect very thin cirrus not detected by other bands. The 1.38 μm band is similar to a band on MODIS (MODerate resolution Imaging Spectroradiometer). Radiation from this band does not sense into the lower troposphere due to water vapor absorption and thus it provides excellent daytime sensitivity to very thin cirrus.

The spectral widths of the ABI infrared bands are shown both in the following Table and Figure. A number of these same bands were selected by NASA for the Advanced Geosynchronous Studies Imager (AGSI) (Hinkal et al. 1999).

Table: ABI channel selection. The four shaded bands denote the proposed additional bands.

Wavelength (µm)	Description
0.64 +/- 0.05	Visible
0.86 +/- 0.05	Visible
1.375 +/- 0.015	Near IR
1.61 +/- 0.03	Near IR
3.9 +/- 0.1	Shortwave IR
6.15 +/- 0.45	Water Vapor 1
7.0 +/- 0.2	Water Vapor 2
8.5 +/- 0.2	IR Window 1
10.35 +/- 0.25	IR Window 2
11.2 +/- 0.4	IR Window 3
12.3 +/- 0.5	IR Window 4
13.3 +/- 0.3	Carbon Dioxide

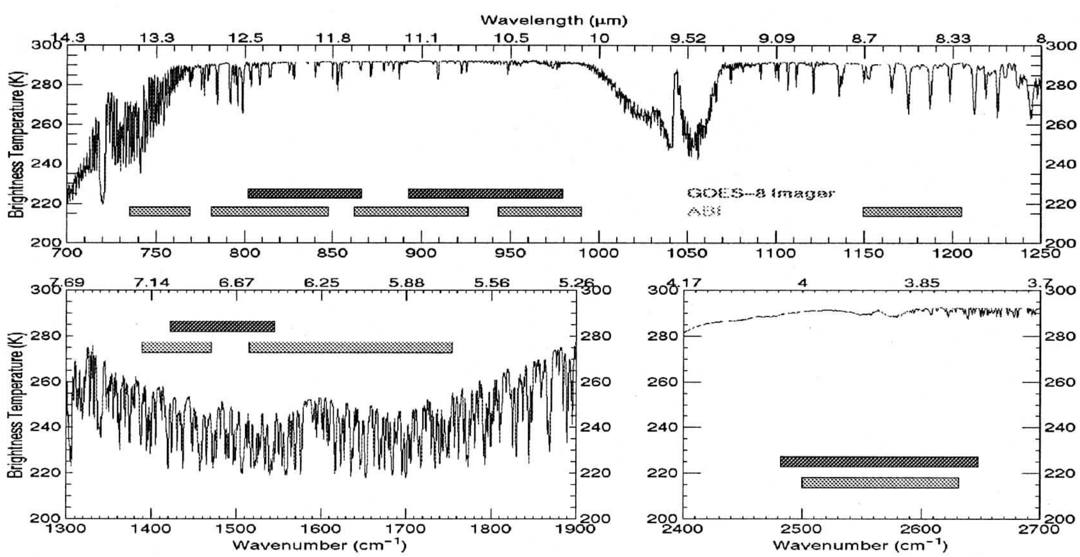


Figure: The GOES-8 IR spectral bands (top bars) and the ABI IR spectral bands (lower bars). A high-spectral resolution earth-emitted spectra is also plotted.

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).

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 a sub-set 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 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.

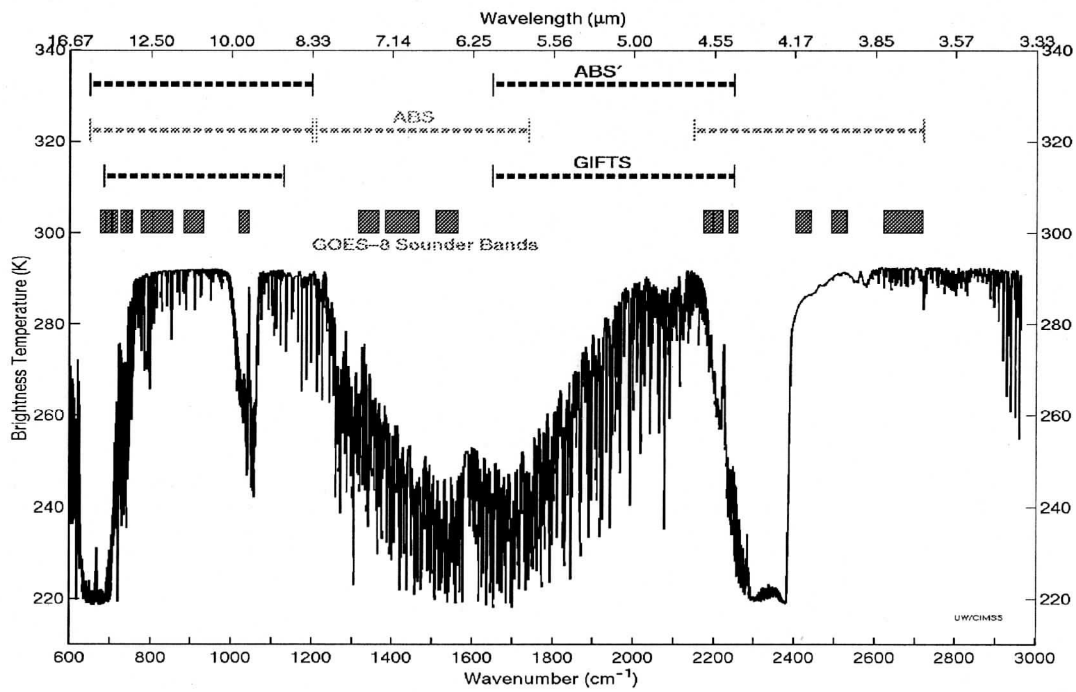


Figure: Spectral coverage of the ABS from 4.4 to 6.2 um and 8.3 to 15.4 um (most recent spectral coverage is indicated by prime, previous coeverage without prime) compared to GIFTS and the GOES Sounder.

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 4.4 to 15.4 microns at 0.625 wavenumber resolution in the longwave; the 25 centimeter optics promises 5 km resolution; a n x n 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 disporportionately. 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-R 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. 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 ORA Instrument Science Team is playing 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/ ORAD	SPC	TPC	EMC	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[a]	X			X			X	X		
Training	X				X			X	X	X

[a] 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/ ORAD	EMC	NSSL	NWS	COMET	FSL	Univ UMD UVA PSU CSU FSU UW	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	3400	1045	240	40	200	X	100	150	800	650
2000	3000	975	250	40	180	X	90	135	740	555
2001	3000	935	250	60	140	X	70	80	850	570
2002	3000	800	220	60	130	X	70	115	950	600

A.3. Summary of Tasks

At the most recent review of GIMPAP activities by the TAC in October 2001 and the following activity summary was generated.

A.3.1. CIRA

CIRA activities include
1. TC genesis / intensity research using imager winds and sounder LI / PW
2. G-12 science test data analysis
3. Ramping up to GOES-R with PC analysis of multi-spectral data
4. geometric height (stereo/cloud shadows) assignment for clouds
5. Severe wx research (storm splitting, outflow boundaries, precip,..) in IHOP
6. Local satellite climatologies
7. RAMSDIS development (and AWIPS enhancements)
8. Outreach activities and training development

TAC guidance is
1. maintain good focus on TC genesis and intensity (in collaboration with CIMSS)
2. keep new developments showing up on VISIT
3. keep POPs informed of product training activities via VISIT
4. establish implementation and transition plan for all products under development
5. prepare geometric height (stereo/cloud shadows) work for use as validation tool of operational wind vector height assignments
6. package principal component analysis tool for broader community use
7. add fog to local satellite climatologies
8. increase coordination with CIMSS and ORA in all areas, especially severe weather research (IHOP,…)
9. continue to guide priorities for future builds of AWIPS
10. prepare to transition modeling activities into proposal to JCSDA next year

A.3.2. CIMSS

Research is planned in
1. sounding and wind algorithm maintenance
2. Eta model moisture and cloud impact studies
3. IR soundings over land (accounting for sfc emissivity)
4. wind vectors with G-12 CO2 heights

5. GOES imager clear sky radiances in NCEP models
6. diurnal ozone studies
7. SST studies (sfc emissivity correction, diurnal trends, model implications)
8. NA ABBA transfer to ops
9. products from multi-satellite multi-sensor combinations (POES/GOES/AERI/GPS)
10. GOES radiance calibration and product validation with CART site obs
11. G-12 checkout
12. Maintain routine GEO-LEO intercalibrations
13. continue outreach activities

TAC guidance is
1. accelerate work on sfc emissivity corrections
2. explore more model independence for NWS FO soundings and DPI
3. enhance collaboration with EMC on EDAS studies
4. explore using sounder moisture depiction over ocean for G-12 SST; coordinate this work with rest of ORA
5. connect with AWC, MPC, and HPC regarding ozone strat intrusion work
6. investigate volcanic ash height determinations with 11 and 13.3 imager data
7. maintain leo/geo intercal algorithm; forego transfer to ops for now
8. coordinate aerosol work (associated with ABBA fire algorithm) within ORA
9. seek more coordination with CIRA on TC work (e.g.PACJET,...)
10. establish implementation and transition plan for all products under development
11. participate in cloud mask unification within ORA
12. keep routine DOE CART intercomparisons as a priority activity
13. prepare to transition modeling activities into proposal to JCSDA next year

A.3.3. OAR / NSSL

Bob Rabin et al propose to
1. evaluate site specific rainfall and PW / LI applications (with CIMSS)
2. explore radar and GOES product merging
3. develop and evaluate basin area GOES auto-estimator rainfall estimates as already started for radar and raingauge in Area Mean Basin Estimated Rainfall (AMBER),
4. participate in GOES training

TAC guidance is
1. rainfall work needs more coordination with Scofield et al in ORA
2. establish implementation and transition plan for all products under development

A.3.4. NWS Outreach

Tony Mostek et al will
1. continue development of platform independent web training materials
2. continue expansion of teletraining activities
3. support satellite meteorology residence courses
4. support outreach projects at forecast offices

TAC guidance
1. coordinate homepage activities with coop institutes and ORA scientists
2. work with NESDIS to evolve GOES

A.3.5. NWS / EMC

Steve Lord et al. propose to
1. continue assimilation of GOES radiances directly into Eta and GDAS
2. continue developing techniques for using land surface products

3. further utilization of Satellite Cloud Products (SCP)
4. improve utilization of diurnal SST

TAC guidance is
1. emphasize assimilation of GOES imager radiances in GDAS
2. resolve problems in Eta caused by using GOES WV radiances over ocean and derived WV layers over land
3. cloud work should be done at highest resolution available
4. initiate study to use sat radiances over land
5. put SST work on hold until product matures (coordinate start with OPOP)
6. need publications of GOES work in coming year
7. prepare to transition proposal to JCSDA next year

A.3.6. OAR / FSL

Dan Birkenheuer et al. propose to
1. expand LAPS to use GOES CTP
2. tune variational error
3. participate in IHOP
4. guide AWIPS products from LAPS experience

TAC guidance is
1. feedback from LAPS western region operational users is not positive
2. seek stronger working relationship with test sites to monitor progress and utility of proposed LAPS products
3. develop implementation plan for operational use of research products
4. work with NCEP on utilization of cloud properties in model
5. prepare to transition modeling activities into proposal to JCSDA next year
6. GIMPAP is not intended for computer support
7. scale activity to resources available

A.3.7. NESDIS / ORA / ARAD

A.3.7.1 Fran Holt

Proposed activities include
1. continue GOES docs
2. maintain web page catalogue

TAC guidance is
1. update CD version of Products and Services Catalog
2. maintain web catalogue with pointers to products and references

A.3.7.2 Gary Ellrod

Proposed activities include
1. continue research in fog, volcanic ash detection, microburst potential, and aircraft icing risk
2. prepare for GOES-12 w/o split window but with 13.3 um

TAC guidance is
1. seek FAA resources for RTVS work (re fog)
2. participate in tele-training activities
3. give cloud base product lower priority; basis for product not well understood
4. contribute to ABI channel selection
5. use MODIS data to test multi-spectral enhancements to existing GOES Imager products
6. seek cloud modeling help for microburst potential research
7. establish implementation and transition plan for all products under development

A.3.7.3 FPDT

Jamie Daniels et al. propose to
1. maintain assistance and backup to IPB for sounding and winds products
2. fix BUFR file distribution of wind and CTP products
3. continue preparations for GOES-12 operations
4. add 4 um winds to ops
5. support new surface and insolation (GSIP) products
6. support IHOP with routine experimental products

TAC guidance is
1. establish a product implementation and transition plan for each product; with such a plan for each product there is too much confusion
2. coordination within other ORA groups missing for some product work
3. IHOP support should be coordinated directly with IHOP team scientist
4. explore hourly wind consistency checks
5. pursue QC of hourly DPI; absence is causing spurious product distributions
6. wrap up implementation of single FOV algorithms
7. correlate GOES sounder results with associated AMSU products
8. conduct trend analyses and/or event related stats of GOES products
9. scale activities to available resources

A.3.7.4.Hydrology Team

Rod Scofield et al propose to
1. improve Auto/Hydro-Estimator
2. explore rainburst adjustment
3. continue POGO (polar microwave rain estimates with geo IR estimates) work
4. demonstrate real time SCaMPR
5. explore neural algorithms
6. engage in QPE verification program over CONUS
7. evaluate model impact over water with EMC

Arnold Gruber et al propose to
1. improve GMSRA
2. incorporate knowledge of cloud microphysical properties into rain algorithm
3. study regional calibrations

TAC guidance is
1. establish implementation and transition plan for all products under development
2. scale activities to available resources
3. continue to evolve Hydro-estimator
4. collaborate with CIRA and CIMSS to use local cloud studies (classification schemes, etc.) for improving rainfall estimates
5. use cloud model as integrator for SCaMPR
6. study high spectral resolution data to prepare for future systems
7. move beyond statistically based toward physically based algorithms microwave plus IR enhancement for rain estimate
8. prepare to transition modeling activities into proposal to JCSDA next year

A.3.8. NESDIS / ORA / CRAD

A.3.8.1 ICT

Mike Weinreb proposes to
1. establish leo vis cal algorithm for GOES
2. insert calibration onto GVAR
3. continue GOES-8 / 10 vis cal trend study using Sonoran Desert
4. perform comparisons with MODIS data

TAC guidance is
1. prepare implementation plan for xfer to ops
2. transition vis cal to real time asap
3. expand vis cal of all GOES including GOES-11 / 12
4. hire person dedicated to these tasks

A.3.8.2 Land Surface Team

Peter Romanov proposes to
1. conclude work on amalgamation of GOES, AVHRR, and SSMI data for better snow cover mapping
2. transfer automated algorithm to ops
3. explore time correlations in snow cover from one region to another

TAC guidance is
1. establish implementation and transition plan for all products under development
2. work closely with IPB in OSDPD
3. use MODIS snow cover in validation efforts
4. explain differences in snow cover products from various sensors

A.3.8.3 Andy Heidinger

He proposes to
1. adapt CLAVR to GOES Imager
2. develop suite of cloud properties and insolation from GOES Imager data

TAC guidance is
1. develop implementation plan for CLAVR based GOES cloud mask and transition plan into ops
2. extend mask to full disk
3. utilize high temporal sampling in algorithm as much as possible
4. organize workshop within ORA to compare and understand the various cloud detection algorithms for various sensors and seek as much commonality as possible

A.3.8.4 Ken Knapp

He proposes to
1. develop GOES Aerosol Smoke Product
2. utilize time continuity of measurements to refine detection and AOT estimation

TAC guidance is
1. develop implementation plan and transition plan into ops
2. use available cloud mask algorithms as much as possible; coordinate with A. Heidinger (ORA) and T. Schreiner (CIMSS) on this.
3. evaluate the expediency of investing resources into further development of GOES-8 AOD product given the current degradation of the visible channels on GOES-8 and anticipated replacement of GOES-8 with GOES-12.

4. address the replacement of GOES-8 with GOES-12 and how the loss of the 12 micron band will effect discrimination of aerosols from clouds as well as the development and implementation of a GOES-12 AOD.
5. evolve the 4-km experimental GOES AOD product to a 1-km product.
6. investigate techniques to ensure accurate surface reflectance parameterization. This is crucial for a realistic AOD product.
7. UW-Madison CIMSS and ORA/ARAD/ASPT have been involved in the area of GOES smoke/cloud detection for a number of years and have developed an experimental GOES AOT product. The investigator should collaborate with CIMSS to take advantage of ORA expertise in the WWB and in Madison.

A.3.9. NESDIS / ORA / ORAD

Eileen Maturi et al propose to
1. maintain operational SST algorithm
2. improve QC
3. account for sunglint
4. utilize POES experience and data

TAC guidance is
1. current product suffers from scan angle dependence
2. co-location file of buoy and clear radiances must be maintained to keep regression SST accurate
3. implementation plan has been wanting for some time
4. coordination with NCEP is not spelled out and appears to be missing
5. RT code must be OPTRAN
6. role of Rutherford Lab and Univ of Edinburg in operational SST not clear
7. multiple funding sources for ORAD work not identified
8. funding withheld until full ORA review of GOES SST product is conducted

A.3.10. NESDIS / ORA

Marie Colton and Paul Menzel will
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

TAC guidance
1. expand user community GOES data access as appropriate

A.3.11. Florida State University

Robert Ellingson et al. propose to
1. conclude study of GOES OLR algorithm
2. map diurnal changes in OLR over NA
3. compare GOES, HIRS, and CERES OLR for different spatial and temporal analyses
4. explore atmospheric energetics in OLR data

TAC guidance
1. finalize implementation plan for xfer of algorithm to NESDIS ops
2. establish user and implementer of OLR product
3. connect with H. Jacobowitz or ORA
4. initiate experimental GOES OLR near real time product
5. scale activity to resources available

A.3.12. CICS (University of Maryland)

Research is underway to
5. establish OLR algorithm for GOES sounder
6. study diurnal changes in OLR over NA

TAC guidance is to
6. link GOES with HIRS algorithms
7. publish results of work

A.3.13. University of Virginia

Jenny Moody et al. propose 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 tropopshere

TAC guidance
1. prepare to transfer algorithm to NESDIS when appropriate
2. focus on normalization of adjusted WV image
3. explore validation avenues
4. keep collaboration with CIMSS on water vapor tracing and ozone retrievals
5. use TOPSY data in studies

A.3.14. Colorado State University

Graeme Stephens
1. concluded study of information content of GOES radiances
2. concluded study of cloud property definition with GOES imager
3. submitted several publications on above

TAC guidance
1. GIMPAP resources were well spent in this research activity

A.3.15. University of Wisconsin

Pao Wang et al. proposes to
1. relate numerical models of cloud top dynamics and thermodynamic structures of T-storms to GOES observations

TAC guidance is (pending successful peer review)
1. collaborate with CIRA (Grasso) and NSSL (Rabin) amap
2. account for radiative transfer in calculation of sensor brightness temperatures

A.3.16. GHCC (MSFC)

William Lapenta et al. propose to
1. use GOES LST in RUC
2. improve cloud discrimination techniques
3. explore small scales below 10 km

TAC guidance is
1. study assimilation of hourly radiances in addition to LST
2. maximize benefit of work for ops as much as possible

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 SPSRBs and other venues, as requested by the GOES Program Manager. This management structure is depicted in the following diagram.

GOES Program Manager
↓
ORA GOES Scientist ↔ OSDPD Product Coordinator
↓ ↓
↑ ↑ ↑ ↑ ↑
ICAPOP SPOP WPOP PPOP --- POPs
↑ ↑
NWS
NASA
University
Product
Management
Plans

Presently Jim Gurka is the GOES Program Manager, Mike Matson 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	I. Guch
Soundings	L. McMillin	E. Brown
Winds	J. Daniels	R. Irving
Precipitation	R. Scofield	J. Paquette
Oceans	B. Pichel	J. Sapper
Ozone	L. Flynn	D. Bowman
Surface	D. Tarpley	B. Ramsey
ERB	H. Jacobowitz	I. Guch
Calibration	M. Weinreb	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, NWS, OAR, NASA, DOD, FAA, and the university community; one meeting a year is suggested. Present members of the TAC are:

Paul Menzel (co-chair)	NESDIS
Mark DeMaria (co-chair)	NESDIS
Jim Gurka	NESDIS
Mike Matson	NESDIS
Don Gray	NESDIS
Leroy Spayd	NWS
Ralph Petersen	NWS
Tom Schlatter	ERL
Gary Jedlovec	NASA
Dennis Chesters	NASA
Steve Mango	DOD
Jim Purdom	CIRA

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.

GOES User Community
↓
product requests
↓
Technical Advisory Committee ↔ Satellite Products and Services Review Board
↓
prioritized needs
↓
GOES Program Manager
↓
resource allocation

APPENDIX C. Product List

This list is current as of winter 2001 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.

PRODUCT	SENSOR	DEVELOPMENT/ IMPLEMENTATION	COVERAGE/ FREQUENCY	USER/ EVALUATOR
Cloud Parameters				
o Cloud Heights (Cloud Top Temp)	Imager	Schreiner/(Daniels) Irving	FD/ 1ph	FAA & NWS/ NCEP
o Site specific Cloud Amount (ASOS)	Sounder	Schreiner/(Daniels) Irving	CONUS/ 1ph	WSFO & NCDC/ NWS
Enhanced Data Sets				
o GOES Projection (WEFAX)	Imager	Ellrod	FD/NH 8pd/2ph	NWS/ NCEP
o Lambert Conformal (AWIPS)	Imager	Ellrod	CONUS/ 4,8ph	NWS & NCDC/ MAR
	(Routine, Rapid Scan)		Hawaii/ 2,4ph P. Rico/ 2,4ph	
o Polar Projection (AWIPS)	Imager	Tarpley	Alaska/ 2,4ph	WSFO & NCDC/ NWS
			NH 2,0ph	

o GVAR Data (real time)	Imager	Ellrod/ Reynolds	Routine, Rapid Scan	NWS/ NCs

Atmospheric Parameters

o Vertical Temperature Profiles (deg K)	Sounder	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
o Layer Mean Virtual Temperatures (deg K)	Sounder	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
o Vertical Moisture Profiles	Sounder	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
o Layer Precipitable Water (mm)	Sounder	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
o Total Precipitable Water (mm)	Sounder	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
	Imager	Schmit/(Daniels) Irving	NH/ 1ph	NWS & NCDC/ SPC
o Channel Brightness Temps (deg K)	Sounder	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
	Imager	Schmit/(Daniels) Irving	NH/ 1ph	NWS & NCDC/ SPC
o Lifted Index	Sounder	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
	Imager	Schmit/(Daniels) Irving	NH/ 1ph	NWS & NCDC/ SPC
o Geopotential Heights (m)	Sounder	Schmit/(Daniels) Irving	CONUS+/ 1ph	NWS & NCDC/ NCEP
o Thermal Wind Profiles (m/s)	Sounder	Schmit/(Daniels) Irving	CONUS+/ 4pd	NWS & NCDC/ NMC & AOML
o Moisture Analysis (Interactive)	Imager	Brown/ Irving	PD/ 4pd	NCEP/ NCEP
o Precipitation Estimates	Imager	Davenport/(Daniels)	CONUS+/ 1ph	NWS & NCDC/ NWS & NCEP
o Precipitation Histograms	Image/	Scofield	30N-30S/ 8pd	NCEP/ NCEP

Data Bases

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

Winds

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

APENDIX 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 (J. Paquette)	WEFAX multispectral products
Soundings and Instruments Team (M. Weinreb)	insolation
CIRA (D. Hillger)	image quality
(J. Dostalek)	multispectral products
CIMSS (A. Schreiner)	ASOS cloud products
(G. Wade)	multispectral products
Satellite Analysis Branch (M. Weaks)	user feedback
WSFO Milwaukee/Sullivan (J. Eise)	ASOS cloud evaluation multispectral product evaluation
WSFO LaCrose (D. Baumgart)	ASOS cloud evaluation multispectral product evaluation
AWC (F. Mosher)	multispectral product evaluation

FSL (D. Birkenheuer)	LAPS impact studies
EMC (J. Derber)	radiance assimilation in GDAS

D.2. Sounding

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

D.3. Winds

Forecast Products Development Team (J. Daniels)	WPOP, software
Product Systems Branch (J. Paquette)	picture pair winds
CIMSS (C. Velden)	upper level winds
(T. Schreiner)	cloud heights from H2O
CIRA (J. Weaver)	storm relative flow
(G. Campbell)	geometric cloud heights
Satellite Analysis Branch (M. Weaks)	user feedback
TPC (M. Mayfield)	wind field evaluations
EMC (S. Lord, G. DiMego)	RDAS/GDAS impact tests

D.4. Precipitation

Hydrology Team (R. Scofield)	PPOP
(C. Davenport)	autoestimator improvements
Satellite Analysis Branch (M. Weaks)	user feedback
EMC (J. Derber)	model impact tests

D.5. Surface

Surface and Atmosphere Team (D. Tarpley)	POP
	land surafce temperature

D.6. Ocean

ORAD (B. Pichel)	OPOP
(E. Maturi)	SST
Marine Applications Branch	model applications

D.7. Earth Radiation Budget

Surface and Atmosphere Team (H. Jacobowitz)	ERBPOP

D.8. Ozone

Soundings and Instruments Team (L. Flynn)	O3POP

D.9. Calibration

Soundings and Instruments Team (M. Weinreb)	CPOP
SOCC	operational evaluation
CIMSS (T. Schmit, M. Gunshor)	cal intercomparisons
CIRA (D. Hillger)	cal intercomparisons

D.10. Navigation

SOCC (K. Kelly, E. Harrod)	NPOP

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

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Menzel, W. P., and E. M. Prins, 1995: Monitoring Biomass Burning with the Next Generation of Geostationary Satellites. Chapman Conference on Biomass Burning held 13-17 March, 1995 in Williamsburg, VA.

Menzel, W. P., and J. F. W. Purdom, 1995: Examples of GOES-8 Data and Products. Optical Remote Sensing of the Atmosphere held 5-9 February, 1995, in Salt Lake City, UT. AMS publication, 2-4.

Purdom, J. F. W., and W. P. Menzel, 1995: Near Term Opportunities and Past Impacts of Space Based Data in Operational Weather Forecasting. 14th Conference of Weather Analysis and Forecasting held 15-20 January, 1995 in Dallas, TX. AMS publication.

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

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

NWS GOES-NEXT Requirements,
April, 1983

APPENDIX F. Providing Information to the User Community

The value of GOES technology to the warning and forecast program must 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 is available through conference presentations, publications in peer review journals, technical reports, and technical information messages. Additional technical information regarding each product is the responsibility of the POPs.

F.1. Conferences

* American Meteorological Society (AMS) Meeting, January 1999, 2000, 2001

* Coordinating Group for Meteorological Satellites, October 2000, 2001

* SPIE Meeting, 1999, 2000, 2001

F.2. Technical Reports

* Introduction to GOES I-M Imager and Sounder Instruments and 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 I-M Data User's Guide
  NCDC
  June 1998

* Preliminary Findings from Geostationary Interferometer Observing System Simulation Experiments (OSSE).
  NOAA Technical Report NESDIS 95
  May 2000

* Current and Future Requirements for Soundings from Geostationary Orbit
  EUMETSAT Technical Memorandum 6
  May 2000

F.3. Training Materials

* 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/infrastructure/overview.html)

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

* 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. 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 were developed. The modules cover the subjects of analysis and interpretation of imager data and understanding and using sounder products. The modules were 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 annual AMS user workshops.

In addition, the NWS conducted 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 provided the trained experts at each NWS office to further lead the efforts on station.

The Virtual Institute for Satellite Integration and Training (VISIT) program provides remote education and training to NWS forecasters on the utilization and integration of modernized data sources. VISIT developed a satellite component of this training through close collaboration with experts at the three NOAA Cooperative Institutes to effectively integrate and maximize the use of satellite imager and sounder data into NWS forecasts and warnings.

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 Imager products SRSO	GOES Sounder DPI Site-specific Soundings GOES/WSR-88D QPE WV winds
Web Training Resources	Satellite Research at NSSL	Satellite Interpretation Discussions GOES 3.9 um Tutorial GOES-8 Tutorial	GOES Gallery at CIMSS WV Imagery tutorial GOES Sounder Tutorial

The Integrated Sensor Training (IST) Professional Development Program and theVISIT provide a critical link between the applied research and development activities of the GIMPAP program and the utilization of new products and techniques within operational forecast offices.

IST/VISIT teletraining sessions (www.cira.colostate.edu/ramm/visit/ecal.asp) in the coming year will

- Conduct approximately 10 to 15 sessions per month
- Develop 7 to 9 new sessions
- Continue improvements in VISITview teletraining software
- Provide support for WMO Virtual Laboratory for Satellite Meteorology
- Provide briefings to NOAA management and staff at AMS and NOAA conferences
- Expand number of instructors to include more NOAA staff
- Incorporate a broader array of satellite products into training sessions
- Include more lessons with instructor's audio

Homepage materials in support of modules and teletraining activities continue to be developed. Coordination with VISIT (including CIRA and CIMSS) continues on the development of a WEB-based training program at the VISIT (www.cira.colostate.edu/ramm/visit/visithome.asp) and Integrated Sensor Training sites (www.meted.ucar.edu/ist). Webpages and materials (coordinated with the NOAA cooperative institutes (CIRA and CIMSS) and with NESDIS Office of Research (ORA) scientists) help support the WMO virtual laboratory for satellite meteorology data utilization that includes links to Web-based tutorials and teletraining sessions.

For FY 2002, the IST and VISIT programs have been requested to develop an organized learning path or distance learning course. This distance learning course will be based on existing teletraining, CD-based and Web-based modules for new satellite focal points in the forecast offices who did not attend a SatMet course.

APPENDIX H. 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
GIMPAP – GOES Improved Measurements and Products Assurance Plan
GMS - Geoststionary 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
METEOSAT – European METEOrological SATellite
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
RSO – Rapid Scan Operations
RUC – Rapid Update Cycle
SAB – Synoptic Analysis Branch (OSDPD)
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
SRSO – Special Rapid Scan Operations
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