

GIFTS PRODUCT ASSESSMENT PLAN

prepared by

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EXECUTIVE SUMMARY

In 2005, with the launch of the NASA Geostationary Imaging Fourier Transform Spectrometer (GIFTS), NOAA will be introduced to a new era of geostationary remote sensing. This new system will expand the geostationary satellite capabilities in support of NOAA programs, both operational and research. NASA will be conducting a GIFTS technology demonstration and measurement validation. NOAA will be investigating the production of meteorological products and a near real time demonstration of operational utility of the new GIFTS data. This NOAA GIFTS Product Assessment Plan is intended to assure the viability of GIFTS products, to develop advanced products, and to ensure integration of the improvements into NWS and NESDIS future operations. Product assessment and assurance is an ongoing effort and must continue to receive high priority so that the opportunities offered by the new geostationary sounding systems for supporting NOAA's mission will be realized.

NOAA participation in the GIFTS technology and data demonstration represents a risk reduction activity in the design of the NOAA GOES Advanced Baseline Sounder and the development of associated algorithms. NOAA is evolving their GOES sounding capability to produce three dimensional depiction of temperature and moisture with better vertical resolution, horizontal resolution, temporal resolution, and broader spatial coverage. NOAA plans to capitalize on the NASA and Department of Navy (DON) investment by allowing for a full and successful transition from research to operations of the GIFTS concept.

NOAA has expressed their commitment to the NASA GIFTS program in a February 2001 letter from Greg Withee to Ghassem Asrar. It points out the respective roles of NASA and NOAA in the GIFTS demonstration

- (a) NASA will operate GIFTS for a period of approximately 12 months over the Continental United States (CONUS) before it is moved to Indian Ocean for use by the Department of the Navy (DON).
- (b) NOAA will infuse GIFTS instrument hardware and engineering design trades into ABS by funding systems engineering support through MIT/LL to the GIFTS, project, as outlined in the proposal received from Langley Research Center (LaRC),
- (c) NOAA will collect and distribute the data necessary to maximize the use of GIFTS data and support research efforts to ensure the readiness of operational product processing when ABS is launched. This includes real time reception and processing on a 24 hour per day seven days a week basis.
- (d) NOAA (through its cooperative institutes) will perform applied research aimed at developing algorithms for using GIFTS data and establishing a stable set of products and nowcasting tools ready for use with ABS, and
- (e) NOAA will make full use of the NASA/NOAA Joint Center for Satellite Data Assimilation to develop efficient assimilation mechanisms, to perform model benefit studies demonstrating the advantages of an interferometer sounder to Numerical Weather Prediction (NWP), and to be ready for ABS data when it becomes available.

A memorandum of agreement between NASA, DON, and NOAA in 1Q02 confirmed the commitment of all three agencies to the GIFTS NASA NMP technology demonstration, familiarizing NOAA to the new geostationary remote sensing capabilities, and transferring the GIFTS to become the DON Indian Ocean METOC Imager (IOMI). It is envisioned that GIFTS launch will occur 4Q05 and that GIFTS operations will defer to a NOAA GIFTS demonstration for about one year in 1Q06. In 1Q07 GIFTS will be moved to the Indian Ocean to become IOMI.

NOAA intends to study the utility of GIFTS data in winter storms over the Pacific, springtime severe storms over the Midwest, and summer / fall hurricanes over the Atlantic. Impact on NWS numerical weather prediction through assimilation of high spectral resolution radiances and multi-level depictions of atmospheric motion will be studied. In addition, impact of GIFTS images and derived products on human forecasting and nowcasting at the NWS Forecast Offices will also be studied.

This plan details the NOAA efforts over the next seven years that include evaluation and validation of the GIFTS products, product enhancements, user training, and evolution toward future products and sensor systems. Input has been coordinated within NOAA. Specifically, the GIFTS Product Assessment Plan

- * Identifies the necessary linkages between NASA and the NOAA organizational elements using GIFTS data, products, and services.
- * Defines GIFTS products, as well as the testing and evaluation necessary to ensure product quality.
- * Identifies strategy for data assimilation, forecasting, and nowcasting tests.
- * Defines satellite schedules that will support NMP technology demonstration as well as NOAA familiarization, product development, and test with advanced NWP models.
- * Identifies procedures for user evaluation and feedback.
- * Identifies resources that are needed to carry out this plan.

Efforts are focused on data access, algorithm development, and data assimilation approaches in FY03 through FY05, near real time demonstration of GIFTS utilization and product validation in FY06, technique development for merging data from many components of a composite observing system and user training in FY06 and FY07, and transition to the start of GOES ABS operations and incorporation of new techniques in FY08 and FY09 and beyond. The GIFTS Product Assessment Plan will be 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 NOAA GIFTS product assessment and assurance activities resides with the "GOES Program Manager", assisted by a "GOES Scientist" with the NESDIS Office of Research and Applications and another "GOES Scientist" within the NWS NCEP. A Technical Advisory Committee (TAC) provides guidance regarding priority and feasibility of future products and sensors. Strong collaboration with the NASA NMP GIFTS team will be essential and accomplished by joint periodic reviews of NMP and PAP progress.

In summary, the NOAA activities during GIFTS Demonstration are

- * GIFTS Level 0 Data Acquisition
 - primary ground system at Wallops
 - backup at UW
 - access to full data stream at UW
- * Data and Metadata Archive
 - some raw data (for NMP team)
 - initially all Level 0 data (for NOAA reprocessing to level 1 with improved algorithms)
 - evolves to Level 1 archive of "golden year" at NCDC
- * Real Time Data Processing
 - Level 0 to Level 1 using software with real time efficiency provided by NOAA
 - Level 1 to 2+ using algorithms and software developed by largely at UW/CIMSS
- * Demonstration of the Utility of GIFTS Data and Products and Distribution to End-Users
 - participation in cal/val intercomparisons of radiances and products
 - real time distribution of GIFTS radiances (compressed or subset) and winds
 - to EMC for NWP impact studies
 - real time web access by selected NWS FOs to multispectral and derived product images
 - of atmospheric water vapor, stability, cloud properties, land surface temperatures,...
 - research on SST, volcanic ash, ERB, trace gases
 - spans winter storms in eastern Pacific (Feb, Mar),
 - severe storms in Midwest (Apr, May, Jun, Jul), and
 - hurricanes in Atlantic (Aug, Sep, Nov)
 - runs 24 hours per day seven days a week as much as possible during demonstration year

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1. INTRODUCTION

1.1 Evolving GOES

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

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

The GOES 8/9/10/11/12 system was a significant advancement in our national geostationary environmental satellite capabilities. Since April 1994 the new generation of geostationary sounders has been measuring atmospheric radiances in eighteen infrared spectral bands and thus providing the capability for investigating oceanographic and meteorological phenomena that far exceed those available from the previous generation of GOES. For the first time operational hourly sounding products over North America and adjacent oceans were possible with the GOES-8/9/10 sounders. The GOES-8/9/10 sounders made significant contributions by depicting moisture changes for numerical weather prediction (NWP) models over the continental United States, monitoring winds over oceans, and supplementing the National Weather Service's (NWS) Automated Surface Observing System (ASOS) with upper level cloud information. Validation of many sounding products was accomplished by comparison with radiosondes and aircraft measurements. Considerable progress was made toward assimilation of soundings from clear skies and cloud properties in cloudy regions in operational as well as research forecast models; GOES-8/9/10 moisture soundings became operational input to the Eta regional forecast model. A GOES Improved Measurements and Products Assurance Plan (GIMPAP) was written to coordinate resource allocation and efforts that assured the opportunities offered by the GOES system for supporting NOAA's mission were realized.

The Geostationary Imaging Fourier Transform Spectrometer (GIFTS) is a revolutionary step in satellite based remote sensing of atmospheric parameters. Using a combination of a Fourier Transform Spectrometer (FTS) and Large Area Focal Plane Arrays (FPAs), GIFTS will measure the Earth emitted infrared radiance at the top of atmosphere from geostationary orbit at an unprecedented combination of spectral, temporal, and spatial resolution and coverage. The instrument will have the capability to trade-off the desired spectral resolution and spatial and temporal sampling inflight upon command. From these measurements, thermal and gaseous concentration profiles, cloud parameters, wind field profiles, and numerous derived products can be retrieved. NASA is introducing GIFTS under the New Millennium Program (NMP) that is primarily a technology validation program; thus much of the algorithm development and data utilization will be the responsibility of NOAA. The GIFTS technology and data demonstration will influence the development the NOAA GOES Advanced Baseline Sounder, which will represent the operational implementation of a geostationary high spectral resolution infrared capability.

1.2 The NASA GIFTS Program

NASA has drafted GIFTS Primary Measurement Concept Objectives that provide the driver for the required accuracies in the retrieved atmospheric parameters, the derived accuracies in the radiometric, spectral, and spatial accuracy of the measured radiance spectra, and the underlying instrument design. Their Measurement Concept Validation Plan lays out the various tasks and data sets that will be used to validate that the desired accuracies in the primary GIFTS products are being attained. It includes the NASA plans and resources necessary for validation efforts, the relation of NASA efforts to other validation efforts associated with GIFTS, and an implementation scenario and contingencies.

In selecting GIFTS for a NMP mission, NASA has stressed the need for pursuing "agreements with future science and/or operational user communities on a well defined infusion approach for the GIFTS measurement concept". NASA is expecting their NMP efforts to be supplemented by NOAA participation in the GIFTS program.

The NOAA participation in a demonstration of operational utility is embraced in this GIFTS Product Assessment Plan. The NOAA efforts are distinguished by the larger scope and data volume associated with operational or quasi-operational use of the GIFTS data. Along with traditional validation (comparison with in-situ sensors, etc...), the NOAA efforts draw largely on the assimilation of the GIFTS data into numerical models to assess the impact of the data on predictions. NOAA involvement will also play a role in determining the desired orbital positions and resulting geographical areas and meteorological conditions seen by GIFTS. NOAA will acquire, process, and archive all the data during the GIFTS demonstration. The peak of the data gathering and assessment activities will take place 3 to 15 months after GIFTS launch.

This GIFTS PAP complements the NASA efforts so that the combined NASA and NOAA plans form a whole.

1.3 Future NOAA GOES Sounders

NOAA participation in the GIFTS technology and data demonstration represents a risk reduction activity in the design of the NOAA GOES Advanced Baseline Sounder and the development of associated algorithms. NOAA is evolving their GOES sounding capability to produce three dimensional depiction of temperature and moisture with better vertical resolution (approximately 1 km) and temporal resolution (hourly full disk soundings) while maintaining the horizontal resolution (approximately 10 km). The ABS will be capable of frequent sounding of the temperature and moisture structure of the atmosphere with a vertical resolution of 1 km (a significant increase over the 3 km possible with the current GOES Sounder), observing the structure of clouds, and inferring the presence and transport of key atmospheric constituents. The ABS will be able to sound the full disk and smaller continental and regional areas at an hourly rate or faster using the 4 - 15 micron portion of the spectrum. Measurement of constituents (tropospheric ozone, CO and other trace gases) and their transport will be accomplished over regional areas on an hourly basis with spectral resolution of about 0.5 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.

1.4 GOES Support of NOAA Missions

NOAA's mission, as detailed in the Strategic Plan, 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) sustain healthy coastal ecosystems, (4) promote safe navigation, (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 geostationary sounder is an integral part of NOAA's modernized observing system and is designed to improve NOAA's ability to perform its mission.

The National Weather Service Strategic Plan for Weather, Water, and Climate Services 2000 – 2005 stresses that two of the goals are to (a) expand and improve the existing weather, water, and climate product and service line with performance measures of reducing the national average tornado warning false alarm rate, increasing the average lead time for hurricane landfall forecasts, increasing the probability of detection of winter storms, and increasing the flash flood warning lead time, and (b) extend the time periods and improve the accuracy and formats of weather, water, and climate forecast products with performance measures of extending weather forecasts to seven days, providing forecasts in probabilistic terms, extending precipitation forecasts, and providing west coast forecasts as accurate as those for the rest of the country. Advancing the geostationary sounding capability will play an important part in achieving these NWS goals.

Establishing the means and methods of effectively integrating advanced GOES soundings (as represented by GIFTS and GOES ABS) 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.

1.5 Improved Products and Services

NOAA/NESDIS will lead, through its Office of Research and Applications and the associated Cooperative Institutes, the efforts to evaluate the improved products and services and to assess their operational utility. Water vapor products consisting of three-dimensional depictions of moisture and associated motions will be studied for their impact in nowcasting as well as mesoscale and synoptic scale weather predictions. High spatial resolution soundings over regions where conventional data are not available will be of particular interest. GIFTS will give NOAA early access to advanced sounding products expected from their future GOES ABS.

A high spectral resolution sounding capability in the infrared region from geostationary orbit has generated high expectations in five performance areas. Specifically, the GIFTS and then the GOES ABS will

- * depict water vapor as never before by identifying small scale features of moisture vertically and horizontally in the atmosphere,
- * characterize life cycle of clouds (cradle to grave) and distinguish between ice and water cloud (which is very useful for aircraft routing) and identify cloud particle sizes (useful for radiative effects of clouds),
- * measure surface temperatures (land and sea) by accounting for emissivity effects (the improved SSTs will be useful for sea level altimetry applications),
- * distinguish atmospheric constituents with improved certainty; these include volcanic ash (useful for aircraft routing), ozone, and possibly methane plus others trace gases, and
- * track atmospheric motions much better by discriminating more levels of motion and assigning heights more accurately.

1.6 Purpose of Product Assessment Plan

The purpose of the NOAA GIFTS Product Assessment Plan is to assure the viability of the GIFTS radiances, to develop advanced products, and to assess the improved measurement capabilities in NESDIS and NWS operations. These efforts will make the GOES ABS capabilities available to both public and private sector users in an efficient, effective and timely manner.

The product assessment through evaluation and validation efforts is accomplished largely within NESDIS, and NWS with university collaboration. The overall management of all GIFTS product assessment activities resides with the "GOES Program Manager", assisted by a "GOES Scientist" with the NESDIS Office of Research and Applications (ORA) and another "GOES Scientist" within the NWS National Centers for Environmental Prediction (NCEP). A Technical Advisory Committee (TAC) provides guidance regarding priority and feasibility of future products and sensors. As the products become mature and operational, the responsibility for maintaining and improving the products resides within the Product Oversight Panels (POPs) of NESDIS.

This GIFTS Product Assessment Plan presents the plans relevant for GIFTS data and products in three key areas: (a) radiance validation; (b) algorithm development and product validation; and (c) user assessment in forecasting /

nowcasting. Section 2 presents the data processing and archive plan. Section 3 presents the evaluation / validation of radiances at level 1b and products at level 2. Section 4 indicates how the algorithms will be developed. Section 5 discusses the implications of improved geostationary measurements. Section 6 outlines an outreach and education activities. Section 7 presents the interactions between NESDIS and NWS in the execution of this plan. Section 8 presents to evolution to ABS. Appendix A indicates the government and university laboratories plus the resources that will be required to assure effective utilization of GIFTS and then GOES ABS products and services. Appendix B outlines the management plan. Appendix C summarized the GIFTS instrument design and its anticipated capabilities. Appendix D cites locations of web sites for further information. An acronym list occupies Appendix E.

2. GIFTS DATA PROCESSING AND ARCHIVE

This summary from the University of Wisconsin-Madison (UW-Madison) provides background information on five required activities for NOAA data processing during the GIFTS demonstration. The contents provide an overview of each activity with discussion of relevant issues, potential solutions with trade-offs, and recommendations. The five activities for NOAA data processing for GIFTS are:

1. GIFTS Level 0 Data Acquisition,
2. Data and Metadata Archive,
3. Data Processing (Level 0 to Level 1, Level 1 to 2+),
4. Development of a Database Foundation Scheme for Archived Data and Products, and
5. Demonstration of the Utility of GIFTS Data and Products and Distribution to End-Users.

The tentative data flow configuration is shown in Figure 1.

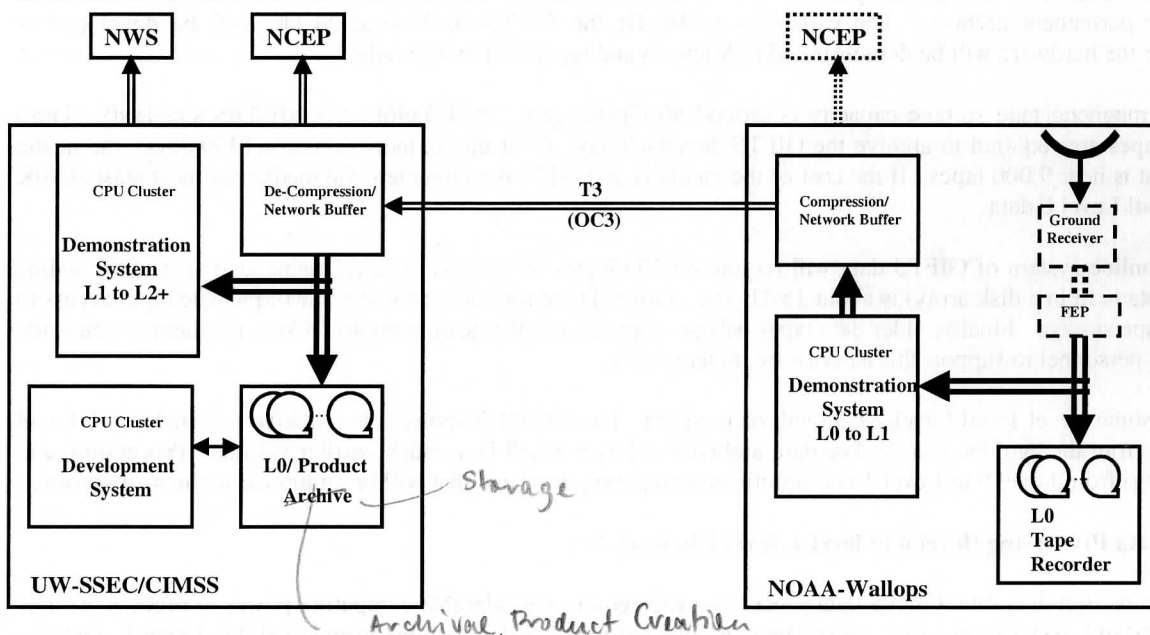


Figure 1. Schematic of GIFTS ground segment illustrating the data flow from the ground reception at NOAA-Wallops, through several stages of ground data processing, to the distribution of end-user products for the NOAA Demonstration of Operational Utility.

2.1 GIFTS Level 0 Data Acquisition

The Wallops CDA will be the primary site for GIFTS X-Band data reception. As the Space Science and Engineering Center (SSEC) at the University of Wisconsin - Madison (UW-Madison) is a major participant in the

GIFTS program a backup GIFTS data acquisition system will be developed at the UW-Madison. A ground communication system will make the full GIFTS data stream available at SSEC/CIMSS. The cost for a leased line capable of the full GIFTS data rate is about \$2.0M for the 12 month GIFTS demonstration period.

The return flow of data to NCEP to conduct real time GIFTS product assessment will be a considerably reduced volume compared to that required at UW-Madison for archive and to conduct real time GIFTS product assessment. The Level 0 to Level 1 data processing algorithm development team (which has been designated to be UW-Madison) will be coordinating extensively with the Wallops GIFTS ground processing system. Fast operational implementation after launch and practical opportunities to develop optimal real time processing strategies will be a primary goal for the SSEC and Wallops teams.

The direct reception facility at SSEC can be created at relatively low cost; SSEC proposes to utilize, with minimal upgrade, existing antenna facilities to receive GIFTS data, and purchase a smaller antenna system to maintain current SSEC data reception obligations. SSEC has an existing 11m C-Band antenna system that will be converted to X-Band.

2.2 Data and Metadata Archive

UW/SSEC proposes to develop a system that will archive all the GIFTS Level 0 data for subsequent reprocessing of selected data sets to Level 1. Figure 1 shows the GIFTS data flow from the antenna system through the ingest of Level 0 (raw interferograms with metadata) and beyond. The GIFTS Level 0 data rate is near 55 mbits/second, or about 1 TerraByte/Day. The volume of Level 1 data (calibrated, navigated spectra) are approximately the same as Level 0. Archiving at Level 0 enables reprocessing with improved Level 0 to Level 1 algorithms as they evolve.

When the algorithms for processing level 0 to level 1 have become stable, the UW level 0 archive will be transcribed into a level 1 archive of the "golden year" of GIFTS data from the NOAA Demonstration that will be transferred to NCDC for permanent archive. The capability to handle the GIFTS Archive at NCDC will be developed at UW/SSEC; the hardware will be demonstrated in Madison and replicated in Asheville.

Currently, magnetic tape storage capacity is around 40 Gbytes (e.g., IBM 3590E, the NESDIS standard). Thus, about 24 tapes are required to archive the GIFTS data each day. Over the 12 month mission (360 days), the media requirement is near 9,000 tapes. If the cost of the media is about \$70 per tape then the media cost is at least \$630K to archive all Level 0 data.

A 10-day online system of GIFTS data will require 8,950 Gbytes of storage. The recommended size of the online archive (data held in a disk array) is about 15 Tbytes. Two 5-Tbyte robotic tape systems will provide rapid access to near-line tape storage. Finally, older data tapes will be stored in an off-line tape library. Costs for these systems, the media, and personnel to support this activity are under review.

Archiving some Level 1 and Level 2 data will be required. The GIFTS Demonstration archive will include all Level 1 data sets from the "golden year". The data archived at Level 2 will be a much smaller volume. Processing (and reprocessing) from Level 0 to Level 1 is a significant computing overhead that will be addressed in the next section.

2.3 Data Processing (level 0 to level 1, level 1 to level 2+)

Because of its high data rate, GIFTS data processing will require considerable computing power to process the data from Level 0 to Level 1 in real time. Since there is little reduction in data volume from Level 0 to Level 1, applying science algorithms to produce Level 2 data will also require significant computing capability. Level 2 data processing will require about 20-25% of the computing capability of the Level 0 to Level 1 processing.

UW/SSEC will develop software for Level 0 to Level 1 and Level 1 to Level 2 products suitable to perform NASA NMP validation as well as conducting the NOAA GIFTS Demonstration. Under the NMP plan, less than 2% of the GIFTS data needs to be processed during the demonstration period. Software developed to support this demonstration will be suitable to meet this demand but will likely require some operator interaction, results

monitoring, and failure contingency intervention. The NOAA GIFTS Demonstration will obligate real time scenarios and associated data volume increases, so the software will be robust and fault tolerant.

Assuming a data rate of 55 Mbytes/sec or 895 Gbytes per day, processing the data as it arrives will require either a large scale symmetric multi processor system (SMP) or a cluster of off-the-shelf PCs running in parallel. Level 1 to Level 2 processing in real time will produce an additional 115 GB per day of Level 2 products. A parallel processing approach is well suited to the generation of products like temperature and moisture retrieval, winds, etc. UW/SSEC has conducted a preliminary trade-off study between SMP and cluster technologies to evaluate suitability of these architectures. In order to confirm architectural assumptions and evaluate performance using PC clusters, plans for more extensive experiments using PC clusters are proceeding at UW/SSEC

A symmetric multi processor system (SMP) system includes:

- Integrated unit with high-bandwidth backplane
- Shared RAM, multiple CPU, single OS kernel
- Communication: shared memory & semaphores
- Examples: SGI Origin, IBM RS/6000

SMP Pros and Cons

- Pro: well suited for general purpose computing
- Pro: vendor supported maintenance contracts available
- Con: high cost per CPU limits scalability

A PC Cluster parallel processing system includes:

- Network of inexpensive off the shelf computers
- Multiple RAM, multiple CPU, multiple OS kernel
- Examples: Sandia 'CPlant', Forecast Systems Laboratory 'Jet'

Cluster Pros and Cons

- Pro: mass market components are readily available
- Pro: scales affordably with low cost per CPU node
- Con: requires custom development and support

Recent accomplishments at a number of research centers have shown the parallel processing cluster approach to be a more cost effective and efficient way to do the data processing. Within the PC cluster / parallel processing environment we have considered the options of building the system internally versus contracting a vendor to supply the hardware with setup. The first attempt to cost out this computing environment shows that contracting with a vendor will likely approach twice the cost of using in house expertise. In either case, the PC cluster system configuration estimate is that real time GIFTS data processing will require 125 CPU nodes running at 150 MFLOPS each to do the Level 0 through Level 2 processing.

The preferred option for Level 0 though Level 2+ processing presently (March 2001) is an SSEC built PC cluster with $94(L0-L1)+21(L1-L2)+10(L2+ \text{ products})=125$ CPU nodes.

This establishes the hardware system for the ground processing. To develop the environment for GIFTS ground processing there must be interface software, ground data processing system engineering, computing infrastructure design, application framework development, integration and test, product generation software, and data distribution..

2.4 Development of a Database Foundation Scheme for Archived Data and Products.

The extremely large data volume produced by the GIFTS instrument necessitates the development of data base management tools early in the implementation period. Previous experience with data collected via remote sensing, such as GOES (2.11Mbits data rate, approximately 2 orders of magnitude less that GIFTS) has shown that rapid access and recovery of archived data can be impeded by a lack of adequate indexing information and data categorization. Commercially available software tools such as Oracle and data base expertise should be employed to

define and develop an appropriate data management scheme. This scheme will promote long term goals to allow data cataloging, browsing, and automated and remote data retrieval.

Thus, to define and develop a data base management cataloging scheme suitable to GIFTS data and products, SSEC recommends that the GIFTS program utilize a commercial off-the-shelf approach to facilitate future comprehensive data retrieval. Remote sensing community standards should be adhered to where appropriate..

2.5 Demonstration of the Utility of GIFTS Data and Products and Distribution to End Users

A key motivation of the GIFTS experiment is to demonstrate the utility and benefits derived from the GIFTS instrument to meet the requirements for the NOAA Advanced Baseline Sounder (ABS). To that end, a number of quality controlled products will be produced and made available in real time to NWS Forecast Offices, to NCEP/EMC, and to the research community. The products that need to be made available include radiances from super channels for model assimilation studies at NCEP/EMC (delivered via land communications lines) and soundings and derived product images for forecaster assessment (delivered via the Web). More specifically SSEC will produce:

- 1) Calibrated, navigated radiances (e.g., super-channels)
- 2) Top of the atmosphere radiance data
- 3) Temperature and water vapor soundings
- 4) Moisture field derived winds
- 5) Cloud products
- 6) Derived products / imagery

Implicit in the evaluation of these products is the necessity of developing quality control and product visualization methods, as well as developing comparative schemes between conventional and other remote sensing data sources. Thus, the following steps are recommended in algorithm development, quality assurance, product generation and visualization.

- 1) Develop degraded GIFTS radiances to simulate GOES sounder radiances
- 2) Advance existing GIFTS algorithms for use in NOAA NWS/NCEP evaluation
- 3) Develop new GIFTS algorithms for use in NOAA NWS/NCEP evaluation
- 4) Develop visualization tools for GIFTS data, including through AWIPS LDAD
- 5) Prepare and conduct an SSEC / CIMSS algorithm test and validation program
- 6) Prepare and assist with an NWS / NCEP evaluation program

Much of the algorithm development will occur at SSEC. Other science centers will collaborate in the SSEC / CIMSS algorithm validation. The NWS / NCEP evaluation program will have broad agency participation.

In summary UW/SSEC in concert with the NESDIS scientists within the cooperative institute will (a) develop Level 3 products (derived from Level 2), (b) develop quality control schemes, including GIFTS visualization, (c) conduct data assimilation evaluation experiments, and (d) develop Web based product dissemination and timely distribution of data products. These activities are described in more detail in Sections 3 and 4; costs are outlined in Appendix A.

3. EVALUATION/VALIDATION

Evaluation/validation of instrument performance and derived wind and sounding products ensure that NOAA realizes improved services through the effective use of the remote sensing capabilities provided by the GIFTS and the following GOES ABS sensors.

In these efforts, the term "validation" refers to product accuracy and resulting instrument performance assessments performed (primarily) by comparisons to external data sources of comparable or higher accuracy. An example is the comparison of GIFTS retrieved temperature profiles to those of coincident research grade radiosondes for a statistically representative set of conditions and resulting conclusions regarding the accuracy of the GIFTS retrieved

profiles. While external data is the primary tool of these efforts, some validation can be performed using GIFTS data alone. For example, analysis of spectra of the on-board calibration blackbodies can be used to assess the radiometric calibration and noise performance. Naturally, the resulting product accuracy assessments can be compared to the product accuracy goals. Logical outcomes are closure, or problem identification leading to feedback to the instrument, algorithm development and/or data processing efforts.

3.1 Characterizing and Validating Radiances at level 1B

NASA will be performing this part of this activity as part of their NMP demonstration; NOAA will perform routine intercalibrations with reference data from ground site and aircraft and other satellite sensors with an emphasis on preparation for GOES ABS. Radiance validation consists of independent assessment of the spectral, spatial, and radiometric accuracy of the calibrated GIFTS radiances. For spectral validation, the efforts are focussed on top-of-atmosphere calculations using known spectral features. For radiometric calibration, the primary validation is done with coincident observations from the aircraft instruments, NASTI and SHIS, with top-of-atmosphere calculations using validation site atmospheric profiles and surface characterization, and with intercomparison with other satellite sensors such as AIRS, IASI, and CrIS as they become available.

3.1.1 Aircraft Radiance Observations

High Resolution Spectral Radiance from GIFTS will be compared with those observed from Aircraft Radiances from NAST-I and Scanning HIS

Techniques that will be required include:

1. Coincident Observing: Conduct an aircraft field campaign in which NPOESS under-flights are made with aircraft flights. Adjust the aircraft view-angle to match the appropriate GIFTS cross-track angle.
2. Target Selection: Select reasonably uniform targets with a range of radiance levels (e.g. uniform ocean for a range of latitudes, deserts, and uniform cloud decks).
3. Spectral Weighting: Basically, the approach is to compare both GIFTS and aircraft spectral radiances at a common spectral resolution. This is possible since the NAST-I and S-HIS are both Fourier Transform Spectrometers as is the GIFTS sensor.
4. Spatial Weighting: The higher resolution aircraft pixels are summed with appropriate weights to represent the larger GIFTS Spatial Response Function. Unsampled regions are represented by using imager data to assign spectra from similar sampled regions.

Ancillary Data Sources will include:

1. Image data from Aircraft-based Imager (MAS) to assess spatial variations over the GIFTS field-of-view.
2. Atmospheric state (from radiosondes supplemented by other high altitude data sources, even including GIFTS retrievals above the aircraft altitude) for input to model used to simplify spectral comparisons.

At least 40 flight hours per year from field campaigns of opportunity will be supported by GIFTS throughout the instrument lifetime to perform this type of validation. If necessary, GIFTS will organize a special campaign during the second half of its first year in orbit to insure that a timely comparison is achieved. The radiometric characteristic of NAST-I and Scanning HIS will be documented before GIFTS launch, in preparation for estimating errors.

The spectral comparison of GIFTS to aircraft spectrometers is based on comparing the direct comparison of radiances. If the calibration of both instruments is perfect and the scene is uniform, the difference between residual spectra will be noise. It will be nearly uncorrelated with wavelength and dominated by the GIFTS single sample noise (many aircraft samples are averaged to match GIFTS spatial sampling). We are looking for differences that are correlated with wavelength that represent consistent radiometric or spectral calibration differences. For reasonably uniform scenes, we expect to be able to detect differences that are on the order of the peak calibration uncertainties for both instruments (less than 1 K brightness temperature for the critical spectral regions). By achieving a number of comparisons, it will be possible to separate consistent, significant differences from differences attributable to spatial sampling errors.

3.1.2. Calculations of TOA radiance at ARM sites

High Resolution Spectral Radiance (Cloud Cleared) from GIFTS will also be compared to calculated clear sky upwelling TOA radiance spectra.

The basic approach is to compare GIFTS cloud cleared radiance spectra to calculations of the upwelling clear sky radiance for NPOESS overpasses of the ARM sites. The calculations will be performed using input from the ARM site temperature and water vapor best estimate products from the Southern Great Plains (central facility). The GIFTS fast model and line-by-line radiative transfer codes will be used to perform these clear sky calculations. The differences between the observed and calculated radiances are then analyzed with respect to the calculation uncertainties (spectroscopic accuracy, fast model parameterization, atmospheric state uncertainty, and surface emissivity and temperature characterization) to assess the accuracy of the observed radiances. These comparisons will be done for all-sky conditions and will therefore serve not only to assess the accuracy of the clear sky GIFTS radiances but also the accuracy of the cloud-clearing algorithm and resulting radiances under cloudy and partly cloudy conditions.

Ancillary Data Sources include:

1. Atmospheric state from ARM site temperature and water vapor best estimates.
2. Low tropospheric T/q from AERI measurements.
3. Surface skin emissivity from the following sources: USGS land type maps, temporal and spatial collocated ground-based SAERI measurements, calculated sea-surface values.
4. Surface skin temperature from broadband infrared measurements at the ARM sites or fitted to the GIFTS observations.
5. Imager Data for assessing spatial variability of surface characteristics.

The calculations will be performed following the ARM site T/q best estimate production for GIFTS observation times. This includes periods using the on-going routine ARM observations as well as periods with dedicated radiosonde launches.

The accuracy of the calculated radiances will depend largely on the specification of the surface temperature and emissivity, as well as the atmospheric state. The surface emissivity and temperature used in the calculations will likely be determined by fitting a linear combination of the known pure scene type emissivities and the effective, area weighted surface temperature such that window region residuals (GIFTS – calculation) are minimized. In this sense, this validation activity does not address absolute calibration accuracy, but rather has an emphasis on spectral and relative radiometric accuracy. That is, the technique of fitting the surface characteristics to the observed radiances sets the residuals to zero in specific spectral regions in the 10 micron region, but allows for meaningful comparisons of the observed and calculated radiances in spectral regions which do not see the surface. The spectral performance of the GIFTS will be assessed by taking differences between the observed and calculated spectra. Using a large number of comparisons, radiometric differences between the observed (or cloud cleared) and calculated radiances will be analyzed statistically using, for example, scatter plots of radiance differences, or distributions of radiances for selected limited wavenumber regions.

3.1.3 Satellite Sensor Intercomparisons

GIFTS radiance measurements will also be compared to measurements from AIRS, IASI, CrIS, MODIS, VIIRS, GOES, and POES

The general technique is to reduce the GIFTS and the validation sensor radiances to the same spectral resolution and to spatially average the data in a consistent manner. Comparisons to the validation sensor radiances are then made for selected scene types of varying homogeneity and signal level.

Intercomparison of the geo – leo high spectral resolution measurements offers an important method for long term calibration for climate records. When polar orbiting sensors (AIRS, CrIS, IASI) do not overlap in time, geostationary interferometer intercomparisons provide reference calibrations that allow transfer of climate records from one sensor to the next.

3.1.4 Calculations of TOA Radiance from Ocean Ship Cruises

GIFTS radiance measurements will be compared to calculations of top of the atmosphere radiance emanating from a uniform source such as the ocean. MAERI SSTs and sondes from ships will be used with a technique is the same as that of the ARM site radiance calculations, but is implemented using a ocean (or appropriately large sea or lake) ship cruise equipped with accurate skin surface temperature and atmospheric profile measurements.

3.1.5 Navigation

Navigation will be validated to ensure that the GIFTS radiances and atmospheric profiles are navigated to Earth located footprints to the required accuracy. Candidate approaches include the comparison of GIFTS images to images for well defined, high contrast coastlines and similar surface features, and the comparison of GIFTS images with MAS, AVHRR, VIIRS and other high spatial resolution image data.

3.2 Characterizing and Validating Derived Products at level 2

NOAA will lead the validation and evaluation efforts for products at level 2. NASA scientists will provide valuable assistance through their EOS validation activities associated with the Atmospheric Infrared Sounder (AIRS). GIFTS and AIRS collocated data will enable intercomparisons of the products from these high spectral resolution sensors. To accomplish field campaign validation, NOAA/NESDIS will consolidate NMP Measurement Concept Validation field campaign needs into its overall plans for instrument validation of NPOESS and MODIS instruments being scheduled for the period.

3.2.1 Water Vapor and Temperature

Water vapor is highly variable in space and time and is difficult to measure in the atmosphere, especially over the dynamic range required for atmospheric applications. Many observing platforms are however making significant improvements in our ability to measure atmospheric water vapor with the accuracy required for satellite validation. A recent workshop held to discuss the current observation capabilities and to define the future needs concluded that (a) moisture demonstrates considerable variability in the horizontal and vertical, (b) measurements of total precipitable water (TPW) from different systems agree within 5 – 10%, (c) ground based profile measurements offer new opportunities to depict rapid small scale boundary layer moisture changes, (d) remote sensing at high spectral IR resolution offers the promise of depicting vertical H₂O layer patterns, (e) assimilation of moisture information is challenging as all observations are interdependent and influence H₂O balance (forecasts are accurate to within 15 – 20% for TPW), (f) moisture profiles are especially useful in NWS Forecast Offices and centers and geo-soundings are very timely for subjective forecasting because pre-storm environments initiate in moist clear skies often near outflow boundaries (which present good opportunities for IR systems), and (g) there is a need for a coherent national program for moisture measurements and NWP utilization.

3.2.1.1 ARM Site Observations

Traditional validation approaches use radiosondes; however recent investigations have increased knowledge on the absolute accuracy of these measurements particularly with respect to their humidity measurement limitations. To improve upon routine sonde measurements, GIFTS soundings will be compared with routine ARM site observations as well (ARM site T/q best estimate). The array of instruments, including a distribution of five AERIs (included in the Oklahoma Mesonet data), will be used for assessing spatial variability.

The basic technique is to use the routine ARM site observations (at the Southern Great Plains site in central Oklahoma) along with dedicated radiosondes to measure the temperature and water vapor profiles for validation of the GIFTS retrievals. Temporally continuous profiling at the ARM sites will be used to assess small scale spatial variability. GOES, surface networks, and the relative variability of the single-FOV GIFTS retrievals will be used to address larger scale spatial gradients. Best estimate profiles and quantitative error estimates will be provided and compared with the coincident GIFTS retrieved profiles which have been interpolated in space (using single-FOV

GIFTS retrievals) to the validation profile locations. Additional information on the technique and estimated uncertainties are given in the supporting document.

The best estimate products produced from the routine ARM observations will be available for validation purposes. During focus periods, sondes will be launched within 30 minutes of GIFTS measurement times and incorporated into the best estimate products.

3.2.1.2 Retrievals from NASTI and SHIS aircraft observations

GIFTS derived water vapor profiles will be compared with those retrieved from NASTI and SHIS, as available from field campaign deployment.

3.2.1.3 Active and In-situ Aircraft-based observations

Low to upper level water vapor profiles from LASE and frost-point and/or Diode Laser water vapor in-situ sensors will also be used in the water vapor intercomparisons.

3.2.1.4 Comparison to ACARS Data

GIFTS temperature profiles will also be compared with ACARS ascent/descent temperature profiles at the UPS hub in Louisville, Kentucky, USA as well as other sites in the USA

This will require:

Coincident Observing: ACARS ascent and descent profiles from the United Parcel Service Louisville hub will be collected coincident with the NPOESS overpasses (nightly).

Target Selection: Fixed target. Louisville airport and other airport to be selected..

Spatial Weighting: The numerous takeoffs and landings will map out a spatial volume in three dimensions which can be weighted appropriate to the GIFTS sounding.

At least 10 days per month will be analyzed for the year following the GIFTS checkout period. The data analyzed will be restricted to the ascent and descent profiles from the Louisville airport location.

The ACARS temperature measurements have been validated to an accuracy of better than 1 K in 0.5 km vertical layers (Feltz, et al., 1999) using a combination of radiosonde and groundbased remote sensing data. An uncertainty in the validation product can be obtained from computing the variance of temperature measurements within the measured data volume from many different aircraft observations. This estimate will include both the ACARS reproducibility error and the natural variability of the atmosphere over the measurement volume.

3.2.1.5 Comparison to Other Satellite Retrievals

Finally, temperature and water vapor profiles from AIRS, IASI, CrIS HIRS, MODIS,... will also be investigated in collocation with GIFTS profile measurements.

3.2.2 Surface Temperature

3.2.2.1 Sea Surface Temperature

A comparison of GIFTS SST, M-AERI (Marine-Atmospheric Emitted Radiance Interferometer (M-AERI) from University of Miami) SST, and buoy SST measurements will be made wherever possible to assist in the interpretation of GIFTS SST and buoy comparisons made elsewhere. Care will be taken to select a reasonably uniform and temporally stable targets with a range of radiance levels encompassing the range of surface temperatures observed by M-AERI and atmospheric water column amounts measured by GIFTS. The imagery will be used to characterize the area for which the GIFTS SST is considered valid. The M-AERI SST value coincident in time with the GIFTS measurement will be weighted by the ratio of the sum of image data window channel radiance over the entire GIFTS field of view to the sum of image data window channel radiances over the portion of the ship

track within the GIFTS field of view. Error bars will be assigned to the comparison to characterize the variability of the scene. When available, high resolution GOES products will be used to characterize temporal change of the scene during the comparison period.

Validation of the GIFTS SST product will begin when the M-AERI SST data is available. Between one and five sets of cruise data is anticipated during the year following the GIFTS checkout period. This effort assumes that MAERI data from a MODIS validation cruise will be available from existing funding.

The comparison of GIFTS SST and M-AERI SST products is simplified by the high absolute accuracy of the M-AERI (order 0.1 K) but complicated by the large mismatch between the GIFTS SST domain (order 45 km) and the point M-AERI measurements. The largest source of uncertainty in the SST product comparison is expected to be the spatial variability within the GIFTS scene. Uncertainty estimates will be developed to allow error bars to be attributed to each GIFTS /M-AERI comparison. The goal of this activity will be to validate the GIFTS SST product to within about 0.5 degree Kelvin over as wide a range of atmospheric column water vapor amounts as possible.

3.2.2.2 Land Surface Temperature

The focus of this activity is to provide a limited number of case studies for the validation of the GIFTS land surface temperature product which take advantage of the accurate point measurements from the University of Wisconsin S-AERI system. Examples of both uniform and mixed scenes will be chosen. For a mixed surface scene, the GIFTS land surface temperature product is actually an emissivity-weighted temperature. This involves collection of surface temperature and emissivity from the S-AERI system co-incident with GIFTS measurements on a limited campaign basis. The DOE SGP ARM site will be used for one of the case studies. Uniform non-vegetated scenes (e.g. desert) will be used in additional case studies. In order to properly handle the GIFTS footprint (5 km), SAERI measurements of the surface emissivity and temperature of one to three pure scene types within an GIFTS footprint are made. KT-19 radiometers are used to monitor surface temperature changes at the sites while the SAERI measurements are made during the overpass. Land surface maps and satellite imagery are then used to create area-weighted emissivities and emissivity-weighted temperatures for direct comparison with GIFTS products.

The S-AERI measurements of land surface temperature and emissivity at the SGP site will be performed once during each season (Spring, Summer, Fall, and Winter) beginning about 120 days after launch in order to capture the sensitivity of the product to changing land cover. The S-AERI measurements at the uniform non-vegetated sight(s) will be performed within one year of launch but timed to coordinate with any supporting measurements.

The standard GIFTS surface emissivity and temperature products (derived for individual 5 km GIFTS footprints) will be validated in this effort. The point measurement accuracy of land surface temperature from the S-AERI is high (order 0.2 K), so the largest anticipated error is expected from the extrapolation to the land surface temperature for the GIFTS footprint based on satellite imagery and a detailed surface emissivity map. The goal of this project is to validate the GIFTS land surface temperature and emissivity products to better than 2 K and 2% over a range of atmospheric conditions.

3.2.3 Winds

Velden et al. (1997, Bull. Amer. Meteor. Soc., 78, 173-195; 1998, Mon. Wea. Rev., 126, 1202-1218) have demonstrated a mature operational wind algorithm which uses the approach of tracking features in water vapor gradients from geostationary satellites (Figure 2). This fully automated satellite wind-retrieval system developed at UW-CIMSS has been operational at the NOAA/National Environmental Satellite Data and Information Service (NESDIS) for many years and provides wind products for national and international users. Wind vector fields are generated globally, at least 4 time periods per day. These wind data are crucial for hurricane/typhoon track analyses, and for incorporation into numerical weather prediction models. The impact has been shown in sophisticated hurricane track forecast models such as the one run at NOAA/Geophysical Fluid Dynamics Laboratory (Soden et al. 2000, Mon. Wea. Rev., 129, 835-852).

Water vapor, in particular, plays a very important role in determining the stability and the chemistry of the atmosphere. Accurate moisture profiles can also be used to infer the tropospheric wind field. Using a time sequence high spatial resolution moisture analyses obtained from geostationary soundings, features at discrete pressure levels can be tracked. It is anticipated that the GIFTS moisture fields will enable generation of high quality water vapor-derived winds. It is the unique combination of the FTS, the LFPA (i.e., an imaging interferometer), and the geostationary satellite observation platform that makes possible these revolutionary wind profiles and moisture transport measurements.

The GIFTS water vapor retrieval algorithm will be developed and tested using moisture imagery from simulated GIFTS radiances. Through simulation, the retrieved moisture profiles and winds can be evaluated against "truth." The simulation of GIFTS radiances will account for the effects of surface emissivity, contrast between surface skin temperature and surface air temperature, clouds, etc. The moisture imagery from successive time steps over cloud-free regions will be used as input to the UW-CIMSS automated feature-tracking algorithm (Velden et al. 1997, 1998). These simulated GIFTS moisture analyses at high temporal frequency will provide targets of opportunity to track over time to infer winds. Experiments will include examining the ability to retrieve tropospheric wind profiles by tracking moisture features vertically collocated in GIFTS analyses. The full potential of this altitude-resolved moisture imagery sequence (retrieved moisture profile imagery at different time steps) with the mature feature-tracking wind technique will be reached when the future geostationary hyperspectral data become available.

It is expected that it will be possible to define motions in the atmospheric at five or more vertical levels with GIFTS. Validation will be accomplished with direct comparisons with collocated GOES cloud motions, stereo (geo-geo and leo-geo) inferences, profiler measurements, and radiosonde observations. Several intercomparison campaigns with aircraft winds measured with MDCRS will be undertaken. Case studies will be performed to show the improvement in diagnosing wind field and forecasting weather developments through the frequent insertion of GIFTS data into mesoscale models.

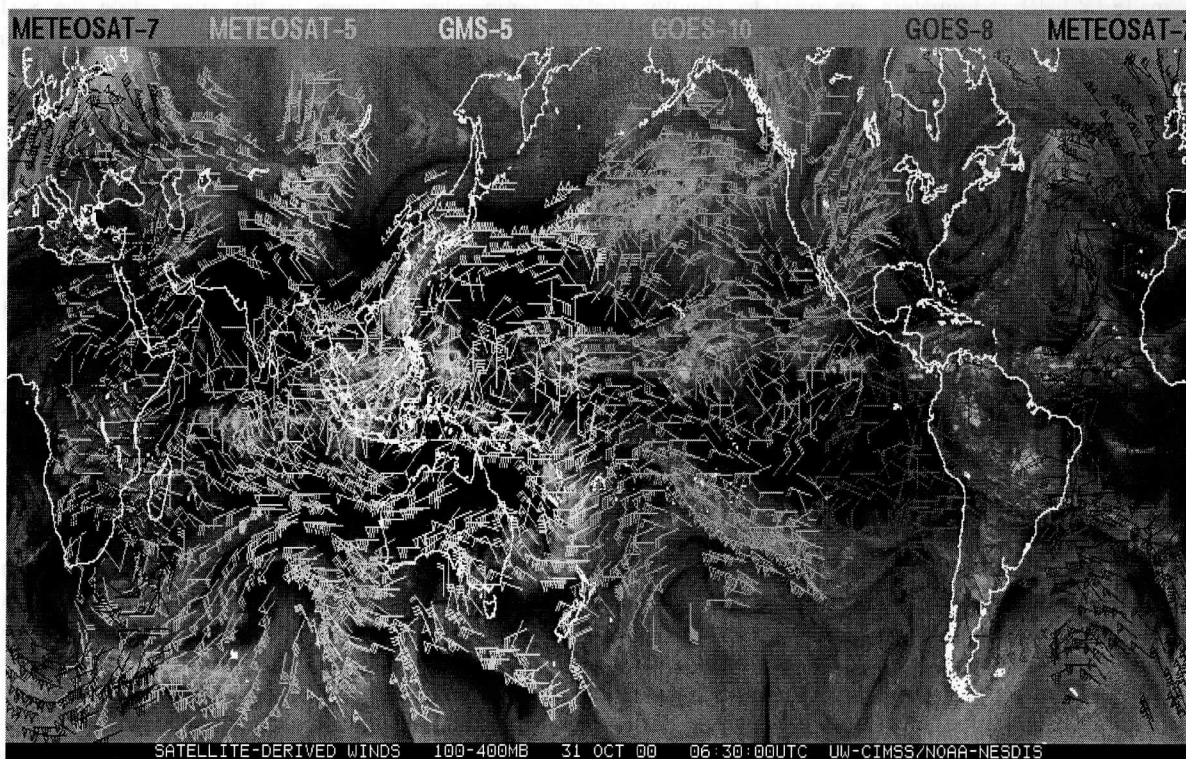


Figure 2. UW-CIMSS global water vapor wind vectors (thinned) for 100–400 mb layer, derived automatically in real time from METEOSAT-5 (cyan color), METEOSAT-7 (blue color), GMS-5 (yellow color), GOES-8 (red color), and GOES-10 (green color) water vapor data.

3.2.4 Cloud Parameters

GIFTS/ABS/ABI radiance measurements will be used for retrieval of atmospheric cloud to pressure (CTP), effective cloud amount (ECA), and cloud phase routinely. Regional cloud products will be generated from GIFTS and compared with the UW HIRS cloud products, International Satellite Cloud Climatology Project (ISSCP) cloud products, and AIRS/MODIS cloud products. The cloud products will be validated using the Lidar cloud measurements and pilot reports. If possible, field programs planned for EOS validation, offer opportunities for cloud product validation through collection and analysis of observations obtained from MODIS Airborne Simulator (MAS; King et al. 1996) and the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Airborne Sounder Testbed-Interferometer (NAST-I; Smith et al 1999)

3.3 Characterizing and Validating Forecast / Nowcast Improvements

The NOAA GIFTS assessment of forecast / nowcast improvements must have both objective and subjective components. These two efforts should be able to merge toward a 'common' processing systems sometime in the near future.

For objective assessment, NOAA must determine how to make the optimal use of the GIFTS (and GOES ABS) data in the operational numerical weather prediction models. 'Measurable' forecast improvement must be demonstrated. The focus will be on mesoscale applications and on the use of data that aren't present in other observing systems (spatial and temporal moisture distributions, ozone, CO₂, etc.).

To do this, NOAA will

- (a) have a consistent and mature common radiative transfer model that is supported by the community.
- (b) have a fast, reliable and completely supported means of getting the GIFTS data to NCEP. This involves having a real-time ground station that can deliver the data to NCEP and decompress it quickly and having a good handle on the channel selection that is needed for the assimilation system. NOAA will be able to learn from AIRS, but computing resources are not available to use all of the channels all of the time. As a first step, NOAA will participate in discussions within the data compression/radiation community (while data compression and channel selection are very different things, they are closely dependent on one another).
- (c) build upon the experiences and development efforts that have gone into AIRS and will go into the GIFTS, but learn how to use the hourly regional GIFTS radiance data in ways that are different from the twice daily global AIRS. This entails

- 1) using the data over land (which involves the surface emissivity issues which feed back to channel selection),
- 2) using the higher-resolution data above clouds (which involves cloud recognition and cloud top characterization, among others),
- 3) exploiting the high time resolution of the data (including moisture/wind tracer relationships, mass field tendencies, ...),
- 4) using trace gas information (ozone, CO₂) both for forecasting and for radiative transfer,
- 5) using the cloud location and structure information in cloud initialization,
- 6) evaluating the contribution of GIFTS in combination with other data sources (e.g., how can the horizontal displays of 1-km resolution vertical moisture profiles information from GIFTS and the detailed, but sparsely located aircraft WVSS data be best used together), and
- 7) tuning the algorithms and data assimilation approaches multiple times.

This is the ultimate goal and will in the long run support both forecasting and nowcasting.

For subjective assessment, the fundamental issue is that forecasters are going to be overwhelmed if they continue to have to look at individual data displays from every instrument that will be available. There is need for 3-dimensional analyses that (a) uses all data, (b) fits all of the data as closely as possible, and (c) quantifies impact of the GIFTS data on the NWS watch/warning process in other than anecdotal ways.

To assure that field forecasters have the support they need for nowcasting as the GIFTS data become available there are two options.

- 1) Continue the ongoing efforts to produce sounder products (specifically emphasizing moisture, in clear air and clouds, and winds) and strive to modify existing nowcasting tools to use these data (and all other high-frequency/off-time data) to full advantage, both in space and time.
- 2) - Develop a parallel variational data assimilation system that produces two sets of analyses - one which is heavily tuned to draw to the data as closely as possible (and isn't concerned about the stability of the forecast) but uses a first guess from a second analysis that is less closely tuned to the data to assure both data retention and background stability.

Either of these options will get forecasters looking at the full mix of data and provide a performance target for the more comprehensive, integrated nowcasting / forecasting system.

3.4 Data Gathering Scenarios

There are data gathering scenarios for calibration / validation conducted by NASA for technology demonstration within NMP and conducted by NOAA for routine assessment of level 1b performance of the radiance measurements. To meet New Millennium Program (NMP) and DON calibration/validation needs for the technology demonstration, NOAA will make the necessary data available to DON and NASA through the Atmospheric Sciences Data Center (ASDC) at LaRC. For the routine level 1b cal/val, NESDIS will consolidate the NMP Measurement Concept Validation field campaign needs into its overall plans for instrument validation of NPOESS and MODIS instruments being scheduled for the same period.

There are also data gathering scenarios for product development and forecasting / nowcasting impact assessment. NOAA intends to collect data for one year to study winter storms in the Pacific, springtime severe storms in the MidWest, and summer / fall hurricanes in the Atlantic. During this year, NOAA will collect GIFTS X-band data in real time with a dedicated ground system available on a 24 hour per day, seven-day per week basis.

3.4.1 Calibration / Validation

The following data gathering scenarios provide enough GIFTS data and collocated validation data in order to address the basic validation in the areas of: navigation (pointing knowledge, stability, and repeatability), radiance (spectral, radiometric, and spatial), temperature and water vapor retrievals, wind retrievals, and data compression. The data is collected over CONUS to make use of the national radiosonde network, the ARM validation sites in the central US, and various other sources of validation data. The data collection is distributed over a one-year time period in order to sample a representative set of meteorological conditions.

The GIFTS orbital location would ideally be ~95 degrees West. From this position, the view angle to the ARM site in northern Oklahoma is a minimum and all of CONUS can be seen with a view angle less than ~55 degrees. An acceptable location would be anywhere between 70 and 125 degrees West. From these locations, the ARM site can be seen with a ~45 degree slant path, and ~90 percent of CONUS is seen with a ≤ 60 degree slant path.

Raw data volume is estimated to be approximately 20,000 "cubes" of data. This is to be divided equally (more or less) among the four seasons (5000 cubes per season). Rational behind this number is given below. This corresponds to roughly 0.6 percent of the total GIFTS data volume; this is equivalent in interferogram data volume to roughly 37600 hours (~4.3 years) worth of NASTI data. A "cube" is defined to be the data collected by GIFTS in its regional sounding mode (0.6 cm^{-1} spectral resolution) in ten seconds. That is, a cube consists of a 128x128 array of 2048 point interferograms for the longwave band, a 128x128 array of 4096 point interferograms for the short/midwave band, the 512x512 arrays of visible data collected during the 10 seconds, any associated auxiliary or metadata (obs times, locations, view angles, etc). The compressed and uncompressed data streams are needed.

A data "browse" capability will be needed to evaluate the current data based on the instrument performance and/or observed meteorological conditions. This information will be used to determine if the collected data is suitable for analysis. For example, GOES imagery could be viewed to determine if the ARM validation site was clear or cloudy during an observation period, and depending on the validation issue at hand, the GIFTS data could be selected for processing, or rejected. This implies the need for a temporary storage buffer that will allow the data to be temporarily (or permanently) stored while this evaluation occurs. Implicit in the need for this capability is that the specific scenes required for product assessment and assurance cannot be specified far in advance, and that all of the data cannot be processed.

Data processing/re-processing for each of the cubes which is selected for analysis, the baseline will be to process the data to the basic Level 1 and Level 2 products (navigated, calibrated radiance spectra, temperature and water vapor retrievals, and wind retrievals.) In light of any data processing/instrument/etcetera complications, the capability to re-process the data needs to be taken into account.

Data processed over the ARM site will cover an area covered by 1 GIFTS cube (512x512 km field of regard). Single cubes centered on the site will be collected every 15 minutes for 2 hours to coincide with the radiosonde trajectories. This will be done for a number of sonde launches for various clear and cloudy sky conditions for a range of temperature and water vapor conditions. This data can be used primarily to address radiance, temperature and water vapor and winds validation. In addition to the radiosonde data, a variety of ARM and other validation from the ARM site domain will be used. To obtain data over a range of conditions, the data collection will be distributed over the 1 year period. $4 \text{ sondes per day} * 8 \text{ cubes per sonde} * 15 \text{ days per seasons} * 4 \text{ seasons per year} = 1920 \text{ cubes}$.

Data processed during an ARM site field campaign will consist of a limited series of GIFTS cubes collected over the ARM site domain. These data will be collected during an intensive field campaign that will involve aircraft and ground based instrumentation. In particular, this scenario will focus on GIFTS radiance validation using aircraft based FTIR observations (NASTI/SHIS) from an ER-2. Additional ground-based and aircraft sensors will be used for temperature, water vapor, and winds validation as well. To estimate the GIFTS data volume, a field campaign with ~50 flight hours (10 flights at 5 hours per flight) is envisioned. During the flights, a GIFTS cube will be collected every 5 minutes for a cube volume of $(50 \text{ hours} * 12 \text{ cubes per hour}) = 600 \text{ cubes}$.

Data processed to achieve polar satellite co-location will be collected in the GIFTS tracking mode (or some other mode which will effectively produce GIFTS data collocated both temporally and spatially with the satellite in question) to collect collocated data with AIRS (on EOS Aqua) and/or GIFTS (on the NPOESS payload). These high spectral resolution satellite data will be used primarily for radiance validation under clear sky conditions. These data will be collected over TBD CONUS locations, over the ARM sites, and over ocean (Gulf of Mexico, western Atlantic, or eastern Pacific). The estimated cube volume is $(1 \text{ cube per overpass} * 100 \text{ overpasses}) = 100 \text{ cubes}$.

There are a number of specific viewing scenarios that are necessary for navigation validation. Navigation validation will be performed using coastline and other data collected during the CONUS observations (discussed below).

Absolute Pointing Knowledge:

Specific coastline and/or star field and/or moon views will be used to assess the absolute pointing knowledge. These views will be performed periodically throughout the year and will be interwoven with other viewing scenarios to assess the navigation before and after other sequences. Estimated count = $1 \text{ cube per scenario} * 100 = 100 \text{ cubes}$.

Repeatability:

To assess the pointing repeatability, a sequence of views of the same scene will be collected. This TBD scene should be clear sky, very stable in time, and have sharp IR features (e.g. clear sky coastline). A single sequence will consist of ~20 views of the same scene. This scenario will be repeated periodically throughout the year. The cube volume is $(20 \text{ cubes/sequence} * 1 \text{ sequence per month} * 12 \text{ months}) = 240 \text{ cubes}$.

Stability:

No specific views are required to assess the stability. Other clear sky scenes can be used to assess the pointing stability during an OPD scan by looking at the stability of the GIFTS visible imagery from 10 second periods.

Spectral normalization scenario:

This purpose of this scenario is to assess spectral calibration/normalization of the GIFTS spectra. A sequence will consist of 5 cubes with the first cube collected such that the on-axis pixel sees the point (x,y) on the ground, the second such that the upper right hand corner pixel sees the point (x,y) on the ground, and so on for the other corner pixels of the FPA. The target will be the ARM site under stable, clear sky conditions. This will be performed only a small number of times. Cube volume is (5 cubes/sequence * 5 sequences) = 25 cubes.

3.4.2 Winds Validation

For winds validation, a CONUS observation viewing scenario (CONUS1) will be used. It also serves as a way to validate the navigation using the coastline, highway, etc. data that is available for CONUS. Temperature and rough water vapor validation can also be performed. The basic viewing scenario is to perform GIFTS water vapor and cloud wind retrievals for the CONUS area. CONUS can be covered with ~50 GIFTS cubes. Each water vapor winds sounding requires 3 views of the same geographic site, with a time step of ~1 hour (ie. obs at 0, 1 and 2 UTC produces 1 water vapor wind sounding for each pixel). Cloud winds sounding can be performed using lower spectral resolution data but with a faster time step (5 to 15 minutes). A CONUS wind sounding will then consist of a water vapor winds sounding with an embedded cloud wind sounding. These will be performed at 0 and 12 UTC to be collocated with the national radiosonde network. Other validation data available at these times (e.g. ACARS, ...) can also be used for the validation analysis. An example viewing sequence will consist of

- 0.6 cm-1 CONUS obs collected at 0 UTC
- 0.6 cm-1 CONUS obs collected at 1 UTC
- ~15 cm-1 CONUS obs collected at 1:15 UTC
- ~15 cm-1 CONUS obs collected at 1:30 UTC
- ~15 cm-1 CONUS obs collected at 1:45 UTC
- 0.6 cm-1 CONUS obs at 2 UTC

The data volume for the ~15 cm-1 obs is negligible when compared to the 0.6 cm-1 obs. The cube volume for such wind soundings is therefore (50 cubes to cover CONUS * 3 views * 2 soundings per day) = 300 cubes per day. These observations will be collected for different meteorological conditions during the 1 year period. The estimated cube volume is (300 cubes per day * 40 days) = 12000 cubes. This will provide soundings for 10 days out of each of the 4 seasons.

A related viewing scenario over CONUS (CONUS2) is one where the wind soundings are produced every 1 hour for a full day in order to demonstrate the time sequencing of wind soundings from geostationary orbit. This will be done for a few case studies and the cube volume will be (50 cubes per CONUS * 24 views per day * 1 day per case * 1 case per season * 4 seasons) = 4800 cubes.

3.4.3 Forecasting / Nowcasting Assessment

The data gathering scenarios for product development and forecasting / nowcasting impact assessment include 12 months of data to study winter storms in the Pacific, springtime severe storms in the Midwest, and summer / fall hurricanes in the Atlantic. During those 12 months, NOAA will collect GIFTS X-band data in real time with a dedicated ground system available on a 24 hour per day, seven-day per week basis. All data will be provided to the National Weather Service's (NWS) National Centers for Environmental Prediction (NCEP) modeling community and also to NOAA's Cooperative Institute for Meteorological Satellite Systems (CIMSS).

NOAA is making plans to receive data from the GIFTS deployment over the continental United States and to distribute processed data in near real time. It is desirable to develop case studies of 30 days each in the winter storm season off the Pacific, the severe weather season in the Midwest, and the hurricane season in the Atlantic. THORPEX off the Pacific Coast in winter 2005-06 will be targeted.

PRODUCT ALGORITHM DEVELOPMENT

The GIFTS PAP will assure that adequate resources are allocated so that the product areas of the current sounder are studied with data from the GIFTS. They include the following areas.

4.1 Soundings

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

Vertical temperature profiles from sounder radiance measurements are produced at 41 pressure levels from 1000 to 0.1 mb using a simultaneous, physical algorithm that solves for surface skin temperature, atmospheric temperature and atmospheric moisture. Also, estimates of surface emissivity and cloud pressure and amount are obtained as by products. The retrieval begins with a first guess temperature profile that is obtained from a space/time interpolation of fields provided by the NWS forecast models. Hourly surface observations are also used to provide surface boundary information. Soundings will be produced from an nxn array of FOVs whenever more than 30% 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. Ten or more precipitable water layers will be integrated from retrievals of specific humidity. These and the total precipitable water are provided in the standard archive.

The selected spectral brightness temperatures are archived with each retrieval. These values are filtered from the nxn 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.

Atmospheric stability indices (such as lifted index, CAPE, ...) for each retrieval will also be derived. The lifted index is an estimate of atmospheric stability that represents the buoyancy that an air parcel will 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 will be available from the retrieved profile. CAPE, another measure of atmospheric instability, will also be 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 currently 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. These winds are most useful in the extra-tropics over water.

Derived product imagery will be produced from the GIFTS data. 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. GIFTS will enable a greater variety of derived product images; the utility of these images for nowcasting and very short range forecasting will be studied by CIMSS in collaboration with the NWS forecast offices.

The overall quality of the current GOES sounding 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. The expected sounding performance of GIFTS has been estimated by radiance simulations. The regional sounding mode simulations have produced rms tropospheric profile errors of less than 1.0 C in one km layer mean temperatures (averaging about 0.7 C in the troposphere) and around 15% in two km layer mean water vapor mixing ratios. The radiometric noise and accuracy requirements for this retrieval of temperature and water vapor in the regional sounding mode with 10 sec dwell time are: (1) noise equivalent radiance (NEN) in the longwave band (685-1130 cm^{-1}) less than 0.2 $\text{mW/m}^2 \text{ sr cm}^{-1}$, or about 0.1 K at 900 cm^{-1} at 300 K (2) NEN in the shortwave / midwave band (1650-2250 cm^{-1}) less than 0.06 $\text{mW/m}^2 \text{ sr cm}^{-1}$, or about 0.3 K at 1600 cm^{-1} at 250 K and (3) absolute calibration accuracy better than 1 K brightness temperature for earth scene brightness temperatures greater than 190 K for the longwave and greater than 240 K for the shortwave / midwave band. It is anticipated that the GIFTS (and the GOES ABS) will be able to outperform the current GOES sounder.

Activities will be coordinated with the Soundings POP.

4.2 Winds

Currently, operational winds are derived every three hours from imager data, from a sequence of 3 half hourly visible and infrared window images. The winds are calculated by a three-step objective procedure that are also applied to GOES images with minor modifications. The initial step selects targets, the second step assigns pressure altitude, and the third step derives motion. An initial altitude is assigned based on a temperature/pressure derived from radiative transfer calculations in the environment of the target. That assignment is determined by using a pressure-temperature profile obtained from EMC forecasts, time and space interpolated to the location of the target. An initial guess motion is used, based on EMC wind forecasts at the estimated cloud level. The cloud motion is derived by a pattern recognition algorithm that locates a "target area" in one image within a "search area" in the second image. For each target two winds are produced representing the motion from the first to the second, and from the second to the third image. The first guess motion, the consistency of the two winds, the precision of the cloud height assignment, and the pattern recognition feedback are all used to assign a quality flag to the "vector" (which is actually two vectors). The horizontal density of the vectors is controlled by the target selector. Initial height assignments are made using H₂O intercept or CO₂ slicing methods. 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 μm from the imager, 7.0 and 7.4 μm from the sounder) are derived by the same methods used with cloud drift imagery. However, the images are separated by a full hour rather than a half hour. Heights are assigned from the water vapor brightness temperature. Water vapor motion vectors are labeled as clear sky or cloudy sky to assist with NWP interpretation of the motion; clear sky represents a layer mean motion while cloudy sky represents cloud top level motion. Validation is accomplished with direct comparisons of collocated computed cloud motions and radiosonde observations. It reveals GOES cloud motion winds to be within 6.5 to 7

m/s with respect to radiosonde observations, with a slow bias of about .5 m/s. Water vapor motions are within 7 to 7.5 m/s.

GIFTS offers an opportunity to improve significantly upon the current GOES wind derivation. Using loops of images in the many narrow spectral channels in the water vapor and carbon dioxide sensitive bands, it will be possible to define motions in the atmospheric at five or more vertical levels. Wind vectors derived from mesoscale model simulations of GIFTS radiances for Hurricane Bonnie have demonstrated the ability of GIFTS to observe the vertical structure of the hurricane circulation. It is expected that the GIFTS wind velocity errors will be much smaller than those associated with current geostationary satellite water vapor radiance tracer results as a result of the much higher vertical resolution of the GIFTS. The revolutionary aspect of GIFTS is that it provides access to the vertical dimension of the wind field, with accurate altitude assignment. Starting with techniques developed for the current GOES, the GIFTS wind derivations will evolve to a final product during the GIFTS PAP efforts. The implications of sensor resolution for deriving winds will be important input to the GOES ABS design. These studies will be coordinated with the Winds POP.

4.3 Clouds

GIFTS will provide greatly enhanced remote sensing capability for the observation of atmospheric clouds. Current low spectral resolution sounders such as HIRS and GOES are limited in their ability to provide information on multi-layer clouds (Menzel et al. 1992), while AIRS, CrIS, IASI, GIFTS, and ABS will overcome this limitation with their high spectral longwave cloudy radiance measurements.

Algorithms will be developed for retrieving cloud-top pressure (CTP), effective cloud amount (ECA; which is defined as the product of the cloud emissivity and the fractional cloud coverage), and cloud phase (water versus ice) from the longwave advanced sounder radiances. Advanced sounder radiances (GIFTS and later ABS) and co-located imaging radiances (ABI) will be directly used to retrieve cloud properties from single FOV. The algorithms can be applied to process the GIFTS data, and in future the ABS/ABI data.

CO₂-slicing will be followed by 1DVAR algorithms for high spectral resolution sounder (e.g., GIFTS or ABS) radiances and co-located high spatial resolution multi-spectral imaging radiances (e.g., GOES Imager or ABI) which retrieve the single layer atmospheric CTP and ECA from a single field-of-view (FOV) with higher accuracy than the current operational sounders (HIRS, GOES).

Algorithms will be developed for high spectral resolution sounder radiances and co-located high spatial resolution multi-spectral imaging radiances which retrieve the multi-layer atmospheric CTPs and ECAs from a single FOV. A simulation study will be carried out to evaluate quantitatively the multi-layer cloud retrieval capability of GIFT/ABS/ABI.

Algorithms will be refined to (a) combine CO₂-slicing plus 1DVAR with high spectral resolution data, and (b) high spectral resolution sounder radiances (GIFTS/ABS) with co-located high spatial resolution multi-spectral imaging data (GOES Imager/ABI).

Studies of cloud properties with GIFTS data will be reported to the Image, Clouds, and Aerosol POP.

4.4 Surface Products

Research is ongoing in several product areas, such as insolation, land surface temperature, and fire detection. GOES estimates of insolation and clear sky land surface temperature have been developed in support of a Land Data Assimilation System (LDAS). In the spring of 1999, NCEP began running a Land Data Assimilation System (LDAS) that aimed at testing, validating and ultimately implementing operationally, a method for estimating soil moisture fields over the Eta domain. Three surface physics schemes were tested in the LDAS. Quantities that force the surface energy and water balance models are precipitation, net radiation, air temperature, humidity, and wind speed. In the LDAS, precipitation and shortwave radiation were determined from measurements, and the remaining variables from the Eta model. The shortwave radiation (insolation) was derived from GOES observations. Insolation is one of the most important forcing variables and one of the most poorly estimated from the Eta model

itself. The surface energy balance models all generate surface (skin) temperature as one of the derived variables. A good diagnostic of the accuracy of the surface physics is by comparing the derived surface temperature with that observed from satellites. Validation and diagnostic analysis of the land surface schemes will make use of surface temperature retrieved from the GOES imager. This form of validation has already proved useful in trouble-shooting the Eta model surface package, and promises to do the same for the LDAS.

The GIFTS surface products will be enhanced appreciably over those available from the GOES sounder. The high spectral resolution enables determination of the surface temperature and the surface spectral emissivity using an absorption line and off absorption line radiances in the infrared window region. These and other surface products will be tested in the LDAS. Activities in this area will be reported to the Surface POP.

4.5 Ocean Products

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. CIMSS and NESDIS Ocean Research and Applications Division (ORAD) have been successful in bringing this product into operations.

GIFTS (and later GOES ABS) offer improved capabilities for SST determinations. With many window channels and an improved algorithm that accounts for surface spectral emissivity, it is expected that GIFTS SST determinations will be within 0.3 C of reference measurements of the temperature of the radiating skin. Activities in this product area will be coordinated with the Ocean Products Oversight Panel.

4.6 Earth Radiation Budget

There are currently no operational earth radiation budget products from GOES. However, based on knowledge acquired from HIRS, AVHRR, and ERBS, the University of Maryland Cooperative Institute for Climate Studies (CICS) is exploring a number of potential GOES products. CICS has begun generating GOES monthly averaged clear and all sky outgoing longwave radiation, clear sky downward longwave flux, and clear sky layer (1000-700, 700-500, 500-250, 250-10 mb) cooling rates as a function of time of day at 30 kilometer resolution. Investigations are beginning into climate phenomena with large diurnal variations and synergy with the International Satellite Cloud Climatology Project. The high spectral resolution offered by GIFTS promises a much better outgoing longwave radiation product. Research will be undertaken to quantify the improvement and its impact on seasonal and inter-annual forecasts. Activities in this area will be coordinated with the Earth Radiation Budget Products Oversight Panel.

4.7 Ozone/Trace Gases/Volcanic Ash

The GIFTS has ozone sensitive channels near 9.6 um useful for diagnosing the origin of mid-tropospheric ozone. Ozone is an important oxidant that can influence the concentration, distribution, and trend of radiatively active atmospheric trace gases, demonstrating a link between chemistry and climate. For example, a major new initiative out of the Atmospheric Chemistry Division at NCAR is proposing a field campaign in the year 2000 entitled "Tropospheric Ozone Production about the Spring Equinox". Total column ozone derived from GOES radiances has been found to be within 10 to 20% of TOMS determinations. This derived GOES product could play a useful role in depicting the formation and fragmentation of stratospheric intrusions which cause a dynamically driven

fluctuating background in mid-tropospheric ozone on which anthropogenic signals of photochemical production are superimposed. Additionally, the channels near the 11 and 12.5 um split window will be useful for tracking volcanic ash. The geostationary viewing allows timely observation of volcanic eruptions and tracking the associated ash. This information is important to the Federal Aviation Administration. High spectral resolution infrared measurements will also provide increased capabilities for distinguishing atmospheric constituents with improved certainty, such as methane and SO₂. Activities will be coordinated with the Ozone Products Oversight Panel as well as the Image, Clouds, and Aerosol POP.

5. PRACTICAL IMPLICATIONS OF ENHANCED GOES OBSERVING CAPABILITIES

5.1 Implications of Improved Products

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

* In the area of disaster mitigation, hurricane trajectory forecasts are benefiting from better definition of mass and motion fields. Recent improvements in GOES wind field estimations helped the Navy prevent unnecessary fleet movements in 1996; Atlantic fleets were correctly ordered to stay in port for nearby but not threatening hurricanes. More generally, considerable savings are realized for every mile of shoreline (and the associated coastal region) that is not unnecessarily evacuated; a 20% improvement in 72 hour trajectory forecasts is projected to be valued at about \$70M per land falling hurricane.

* Improved knowledge of the moisture and thermal field will provide better data for agricultural forecasting and nowcasting. It has been estimated that improvements in three day forecasting of location and timing of rain events (on the order of 500 miles and 12 hours) will 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 will 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, will 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 enhanced GOES capabilities are many and great. With the current GOES imagers and sounders there are early indications that the promise of the GOES is beginning to be realized.

6. GIFTS EDUCATION AND PUBLIC OUTREACH PROGRAM

The goals of the Education and Public Outreach Program for the GIFTS Demonstration are to enhance the broader understanding of science in general and weather/climate in particular among the public and K-16 students. Space exploration continues to be a high interest topic for school students and the public alike. Exploiting this interest to prepare a more science literate next generation is facilitated readily through the education and public information opportunities provided by the GIFTS demonstration.

The K-12 science, math and technology education efforts are best supported by providing mission related and standards compliant materials for teachers and students, and to improve the public's awareness of the contributions to weather observations and prediction through advanced technology.

The GIFTS Demonstration Education and Public Outreach effort is centered around one of the missions primary measurements - atmospheric water vapor. In collaboration with the Global Learning and Observations to Benefit the Environment (GLOBE) supported by NASA, NOAA and the EPA, the Office of Space Science Education (OSSE) at the University of Wisconsin-Madison has developed an inexpensive Sun Photometer to measure atmospheric water vapor using Light Emitting Diodes (LEDs) as detectors. These photometers can be used by students from any of the more than 10,000 schools in 97 countries, to make measurements of atmospheric water vapor and report them routinely to a central site via the internet. These school-based observations can then be used to validate the space based measurements to be made by the GIFTS.

The GLOBE Program offers national and global reach for the GIFTS Demonstration Education and Public Outreach efforts through its teacher training support and partnership with the scientists. By enabling the students to act as scientists looking at research GIFTS data, students gain an invaluable learning experience and scientists benefit from a global dataset. GLOBE has already accepted water vapor as a special measurement, enabling interested schools to participate in the observation effort. GLOBE Students use specially designed protocols and methods to collect data for investigations in atmosphere, hydrology, land cover/biology, soil, and global positioning systems, all of which are consistent with the GIFTS Demonstration science and technology objectives.

The SSEC Office of Space Science Education can provide the Water Vapor and Haze Sun Photometer and provide training in the Water Vapor Protocol. The schools need to have GLOBE certified teachers; they will be solicited from urban and rural areas to help validate the spatial resolution of the water vapor measurements.

7. ORGANIZING THE PRODUCT ASSESSMENT ACTIVITIES

7.1 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.

7.2 Role of the TAC

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

7.3 NWS participation

The user evaluation within the NWS will primarily occur at the EMC 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. Algorithms will be adjusted based on NWS recommendations to the POPs and the SPSRB.

7.3.1 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.

7.3.1.1 EMC

An extensive effort is underway at EMC to develop the Eta Data Assimilation System (EDAS), which is capable of accepting data on frequent (e.g. 3 hourly) cycles for both level and layer parameters. Thus EMC plans to be in position to exploit the spatial and temporal information available from the GIFTS products (e.g. radiances, cloud- and water vapor tracked winds, temperature retrievals, layer moisture retrievals, cloud top temperatures). Additionally products such as snow and ice cover, total ozone, and surface temperature provide information that cannot be provided by other sensors. All parameters will also be used by the Global Data Assimilation System (GDAS), but on a 6-hour cycle.

Impact of a given GIFTS product will be measured by the EMC in a series of tests where the EDAS (and/or GDAS) is run with and without the GIFTS information. Feedback from these tests is being funneled through the POPs and appropriate product availability is being arranged or the desired product adjustment pursued.

7.3.1.2 SPC and AWC

GIFTS and GOES ABS will significantly enhance the utility of satellite data in severe weather forecasting. The improved spectral resolution will provide cleaner windows to the earth surface, sharper detailing of atmospheric moisture, and better definition of cloud properties (such as the cloud height, emissivity, and phase). The geostationary 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 will be working with scientists from NESDIS, CIMSS, and CIRA to explore these new opportunities.

7.3.1.3 TPC

The TPC uses both the imagery and the derived winds provided by the GOES system. GIFTS and hopefully GOES ABS will be capable of producing high density water vapor drift winds at multiple levels in the troposphere along with cloud drift winds with improved height definition. These satellite winds are useful for inferring mean atmospheric motions associated with tropical cyclones and their steering currents. TPC forecasters will continue to work with NESDIS, EMC, AOML, CIRA, and CIMSS scientists to utilize the improved GIFTS and GOES ABS imagery and to evaluate the impact of the new wind sets on their forecast procedures and their model initializations.

7.3.1.4 HPC

The improved depiction of tropospheric moisture and cloud properties will be useful for inferring rainfall potential as well as flash flood threats. HPC scientists will work with NESDIS, EMC, CIRA, and CIMSS scientists to utilize the improved GIFTS and GOES ABS measurements and to evaluate the impact of the new moisture data sets on their forecast procedures and their model initializations.

7.3.2 NWS Field Offices

GIFTS derived products will be relayed to various NWS field offices in real time to assess the impact in nowcasting / forecasting. The maturing Virtual Institute for Satellite Integration and Training (VISIT) will be enlisted to assist with user familiarization and training.

8. EVOLUTION TO THE ADVANCED BASELINE SOUNDER

8.1 ABS design concept

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

8.2 Challenges

Data processing is a significant challenge. Currently available A/D converters are adequate for an initial implementation. However, more rapid readout rates will allow for improved S/N due to the ability to retrieve and average multiple scenes. Cutoff wavelengths of longwave photo-voltaic focal plane arrays are now approaching 15 microns, the desired longwave cutoff. Space qualified active cryo-coolers are currently available that can provide cooling of these focal planes to about 65 K 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 piezo-ceramic wafers and piezo-ceramic linear motors) as well as linear magnetic suspension systems are currently under development that may further improve performance.

APPENDIX A. Tasks and Cost

Product assessment and 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.

A.1. Activity Areas

	NOAA ORAD/ ARAD/ CRAD	NCEP/ EMC	NWS/ WSFO	Univ CIMSS	CIRA	SSEC
Ground System						X
Images	X		X	X	X	
Clouds	X		X	X		
Soundings	X	X		X	X	
Winds	X	X		X	X	
Other ^a	X	X		X		
Outreach & 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	NESDIS/CIMSS/CIRA	NWS	SSEC	FY Total
2003	945	315	325	1585
2004	1155	840	2280	4275
2005	1155	1930	3195	6280
2006	1155	1155	735	3045
2007	2100	1260	205	3565
2008	2100	1260	105	3465
<u>2009</u>	<u>1890</u>	<u>1050</u>	<u>105</u>	<u>3045</u>
2003-09 Totals	10500	7810	6950	25260

Average Annual Cost - \$3.6M

A.3. Summary of Tasks

A.3.1 FY-2003 activities related to GIFTS calibration / validation and transition to operational geostationary high spectral resolution sounding

The following summary approximates costs associated with coordinated GIFTS science assessment and product implementation activities at NWS (primarily NCEP), NASA-DAO and NESDIS-ORA. It focuses on activities that go beyond the scope of the NMP funding of GIFTS, but are essential to achieve operational benefits from the instrument within the shortest possible time after launch. The following activities will be performed in addition to the NCEP Data Assimilation tasks included under the JCSDA.

A.3.1.1 SSEC GIFTS FY03 activities

Data reception, processing, and archive (Task 0)

SSEC will define and develop a data base management cataloging scheme suitable to GIFTS data and products. A commercial off-the-shelf approach to facilitate future comprehensive data retrieval will be pursued. Remote sensing community standards will be adhered to where appropriate. Interface with algorithm development will be started.

SSEC will work with NESDIS to develop hardware designs and processing procedures to allow the full volume of GIFTS data to be received by SSEC and NESDIS. This activity is aimed at data reception and ingest capability sufficient to provide data during the year-long NOAA assessment over the US. SSEC and NESDIS will work with the GIFTS project to refine a plan for cost-effective reception of the GIFTS data which satisfies the needs of both NASA and NOAA. Hardware/software acquisition will follow in subsequent years.

FY	Task	0	SSEC Total
2003		325	325

A.3.1.2 NESDIS-ORA GIFTS FY03 activities

Algorithm Development (Task 1)

ORA will team with the GIFTS science team to develop and implement algorithms for generating sounding and wind products from the GIFTS radiance measurements. This activity will also extend these algorithms into operational form applicable to the planned GOES Advanced Baseline Sounder.

In FY03, ORA/CIMSS will be: (a) developing multispectral cloud detection techniques to account for cloud contamination effects on the sounding retrievals; (b) establishing several case studies from aircraft interferometer data as well as simulated data that will be available to the high spectral resolution user community; (c) investigating information content of measured spectra and accuracy of derived temperature and moisture profiles; (d) conducting sensitivity studies on sounding products to quantify spectral resolution (importance of resolving CO2 lines), spatial resolution (finding clear holes), and calibration requirements (calibrating radiances within technical standards); and (e) beginning investigation of data compression options and their impact on retrievals, especially whether data compression should be in the interferogram or spectral domains.

Data Assimilation (Task 2)

ORA will work with NCEP/EMC modeling scientists on the assimilation of high temporal and high spectral resolution radiance along with other available remote and in situ sensing data into a coherent depiction of the atmospheric state. This activity will include transmittance model refinement, generation of adjoint operators, extrapolation of the atmospheric state into the near future in a nowcasting display, and forecasting six hours to three days forward with numerical weather prediction models. There will also be some effort to conduct observing system simulation experiments in preparation for utilization of these unique data.

In FY03 ORA/CIMSS will be (a) evaluating the impact of improved water vapor and wind fields in mesoscale and synoptic scale weather predictions using aircraft interferometer data as well as simulated data; (b) starting development of a fast transmittance model and the adjoint essential for direct radiance assimilation by NWP; (c) starting implementation of a data assimilation s/w package to prepare for utilization of GIFTS products or measurements in an NWP model; and (d) investigating approaches for assimilating the information content of the complete measured spectrum, especially whether super channels retain enough of the information content.

GIFTS / ABS Synergy (Task 3)

ORA will contribute to OSD planning for the GOES ABS based on GIFTS design, instrument test, and post launch experiences. This involves working with remote sensing instrument experts to refine the trade space of instrument design versus instrument capability based on satisfying user requirements. It is the goal of this activity to foster a convergence of GIFTS and ABS as much as possible.

In FY03 ORA/CIMSS will be: (a) evaluating possible technology infusions such as focal plane detector arrays, signal processing schemes, data compression algorithms, and optical alignment strategies; (b) analyzing trade-off issues relating to spectral channel co-registration, signal-to-noise, and others that may arise in the drafting of a geosounding Technical Requirements Document (TRD); and (c) attending various GIFTS and ABS meetings.

Operational Validation (Task 4)

ORA will participate in NASA field experiments planned for instrument performance calibration and validation. This will include intercomparison with radiance measurements and products derived from other remote sensing instruments (e.g. GOES sounder and imager, HIRS and AVHRR, AIRS and MODIS). ORA will further generate operational calibration / validation procedures to be implemented by the SOCC and OSDPD.

In FY03, ORA/CIMSS will be (a) working with OSD to define the necessary ground system to enable reception and processing of GIFTS data for NOAA pre-operational evaluation; and (b) defining data archive systems and procedures necessary to capture the required data.

FY	Task	1	2	3	4	NESDIS Total
2003		210	315	315	105	945

A.3.1.3 NCEP GIFTS FY03 activities

Data Assimilation (Task 5)

Working jointly with NESDIS, NCEP will combine OPTRAN forward model development and data handling / QC efforts. Development will begin with OPTRAN work and add cloud identification / clearing approaches.

Nowcasting Development (Task 8)

This joint NCEP/NESDIS activity will seek innovative data assimilation and nowcasting techniques which will retain detailed spatial and temporal information unique to GIFTS in frequently updated, objective short-range forecasts. Preliminary evaluation of new techniques will be done using research quality, high resolution GOES sounder products. Assessments will be performed at NCEP Service Centers and WFOs. Final assessments will be done in parallel with field evaluation of GIFTS Derived Image Products. Some of these development activities will be done jointly with NESDIS ORA.

In FY03, efforts will focus in the areas of a) developing transport techniques which retain the spatial moisture and equivalent temperature gradients observed in current GOES sounder image products throughout 3 to 6 hour forecasts using current nowcasting models and b) developing “dynamically-constrained, synthetic” data assimilation tools for retaining Geostationary Sounder information by projecting asynoptic data forward and backward in time.

FY	Task	5	8	NCEP Total
2003		210	105	315

A.3.2 Budget estimates through FY09 for GIFTS reception / processing, calibration / validation, archive, and transition to operational geostationary high spectral resolution sounding

The following summary approximates costs associated with coordinated GIFTS data reception, science assessment and product implementation activities at SSEC, NWS (primarily NCEP), and NESDIS-ORA. It focuses on activities that go beyond the scope of the NMP funding of GIFTS, but are essential to achieve operational benefits from the instrument within the shortest possible time after launch. As an additional point of reference, the annual funding for VAS assessment in FY1980 \$ was approximately \$1.5M per year for five years (compared with \$1.7M per year for the GIFTS PAP). After including the effects of inflation, the estimates provided here are below that level.

A.3.2.1 SSEC GIFTS Ground Reception, Processing, and Archive Activities

Data reception, processing, and archive (Task 0)

SSEC will adapt an existing antenna to receive GIFTS X-band direct broadcast data, archive the raw data signal, preprocess the data into level 1 form in near real time, and distribute radiances and derive products to NWS centers. Budget estimates to accomplish these tasks were summarized in Section 2; those estimates are repeated here along with one person year per year to interface with algorithm developers (note the research and development for science applications are not included in these number – those follow in the other tasks)

FY	Task 0	Comment
2003	325	develop data base foundation scheme
2004	2280	perform antenna alterations for GIFTS, establish data processing h/w
2005	3195	establish archive, establish ground processing s/w, interface with alg dev
2006	735	tapes and manpower for archive
2007	205	maintain archive
2008	105	data distribution
<u>2009</u>	<u>105</u>	data distribution
2003-09 Totals	6950	

Outreach and Training (Task 9)

SSEC will conduct a GIFTS Demonstration Education and Public Outreach effort that includes

- 1) maintaining an informational web site for the GIFTS Demonstration for the public and K-12 students
- 2) developing, calibrating, and distributing Multi-Channel Water Vapor/Haze Sun Photometers to participating schools
- 3) conducting teacher training workshops and train-the-trainer workshops for GLOBE
- 4) collecting water vapor/haze data from GLOBE and validating initially with GOES and MODIS in preparation for validating with GIFTS
- 5) developing displays and exhibits on GIFTS with museum partners
- 6) conducting school visits, public lectures, and events at local, regional and national venues that highlight the GIFTS Demonstration and its science and technology objectives
- 7) developing posters, lithographs and other informational/educational materials
- 8) supporting the atmospheric science and technology curricula at the K-16 level through GIFTS relevant materials
- 9) making presentations at professional conferences (AMS, AGU, NSTA) and workshops.

The GIFTS Demonstration Education and Public Outreach efforts will be undertaken concurrently with the mission development, launch, validation and operational phases (FY 2003 - FY 2007). This is necessary for a lasting impact on both the K-12 community and the public. To achieve the specific objective of water vapor validation with student photometer measurements, a number of teachers must be trained so they can share with their students the skills/techniques necessary to collect the observations. This will require activities in anticipation of GIFTS launch to assure the readiness of the GLOBE network during the GIFTS Demonstration.

The estimated budget need to sustain these efforts follows. A total of \$1,542,512 is requested for the period between 1 October 2002 and 30 September 2007, with an average annual budget of approximately \$300K. This is less than 1% of the total GIFTS budget and less than the 2-4 % budget guideline for similar efforts applicable to NASA's Office of Space Science missions at present.

FY	Task 9	Comment
2003	0	organize outreach efforts
2004	276	finalize photometer development, start high school training
2005	299	engage GLOBE partners in GIFTS Demo, continue training
2006	314	conduct GIFTS GLOBE Demo
2007	325	publicize GIFTS GLOBE Demo success
2008	328	transfer GIFTS ideas to ABS outreach
<u>2009</u>	<u>0</u>	case study distribution
2003-09 Totals	1543	

A.3.2.2 NESDIS-ORA GIFTS Assessment Activities

Algorithm Development (Task 1)

ORA will team with the GIFTS science team to develop and implement algorithms for generating sounding and wind products from the GIFTS radiance measurements. This activity will also extend these algorithms into operational form applicable to the planned GOES Advanced Baseline Sounder.

Data Assimilation (Task 2)

ORA will work with NCEP/EMC modeling scientists on the assimilation of high temporal and high spectral resolution radiance along with other available remote and in situ sensing data into a coherent depiction of the atmospheric state. This activity will include transmittance model refinement, generation of adjoint operators, extrapolation of the atmospheric state into the near future in a nowcasting display, and forecasting six hours to three days forward with numerical weather prediction models. There will also be some effort to conduct observing system simulation experiments in preparation for utilization of these unique data.

GIFTS / ABS Synergy (Task 3)

ORA will contribute to OSD planning for the GOES ABS based on GIFTS design, instrument test, and post launch experiences. This involves working with remote sensing instrument experts to refine the trade space of instrument design versus instrument capability based on satisfying user requirements. It is the goal of this activity to foster a convergence of GIFTS and ABS as much as possible. In 2009, this activity will focus on designing the GOES ABS operational data processing system with OSDPD; algorithms will be sized and operational procedures will be drafted.

Operational Validation (Task 4)

ORA will participate in NASA field experiments planned for instrument performance calibration and validation. This will include intercomparison with radiance measurements and products derived from other remote sensing

instruments (e.g. GOES sounder and imager, HIRS and AVHRR, AIRS and MODIS,...). ORA will further generate operational calibration / validation procedures to be implemented by the SOCC and OSDPD.

These activities must start as soon as possible. GIFTS is intended for launch in 2005 with one year over North America and then five years over the Indian Ocean. The GOES ABS is intended for launch in 2012.

Budget estimates for these four NESDIS/ORA activities are as follows. An ongoing activity is envisaged. Note that NESDIS costs are 105K/person year.

FY	Task	1	2	3	4	Total	Comment
2003		210	315	315	105	945	start work with GIFTS team
2004		420	315	315	105	1155	build tools for assimilation tests
2005		420	315	315	105	1155	finalize RT and product alg
2006		420	315	315	105	1155	conduct GIFTS demo
2007		630	315	105	1050	2100	perform data assimilation tests
2008		630	420	---	1050	2100	alg upgrade, redo assimilation tests
2009		420	420	---	1050	1890	alg upgrades, ABS preparations
<hr/>							
Total		3150	2415	1365	3570	10500	

A.3.2.3 NWS-NCEP GIFTS Activities

Data Assimilation (Task 5)

This joint activity with NESDIS and NASA-DAO will combine OPTRAN forward model development and data handling / QC efforts. Development will begin with OPTRAN work, add cloud identification / clearing, and shift to clear radiance quality control in 2005. After GIFTS launch the assimilation of real data will dominate.

Data transmission operations for DA (Task 6)

NESDIS will explore developing an X-band receiver site for GIFTS data and distributing these data to NCEP. Additional resources will also be required at NCEP to ingest these data in real-time. Specifically, NCEP will require a 1-time computer purchase and personnel for data subsetting system development and systems administration and monitoring. Subsequent data collection when GIFTS is positioned over the Indian Ocean will be accomplished by the Australian Bureau of Meteorology.

Data impact tests (Task 7)

Mesoscale and global model tests will be conducted to assess the impact of the various GIFTS data sets in various different NCEP model application. Specific sensitivity tests will assess the impact of (a) winds and moisture on hurricane models, (b) winds on global models, (c) winds and moisture on storms-scale models, and (d) cloud properties on aviation-related products. Parallel runs of NCEP model will be made and assessed within NCEP/Washington and appropriate Service Centers, as well as at WFOs via Internet. NCEP will provide super-computer time and NWS regions will provide assessment personnel at WFOs.

Nowcasting development (Task 8)

This joint NCEP/NESDIS/University activity will seek innovative data assimilation and nowcasting techniques which will retain detailed spatial and temporal information unique to GIFTS in frequently updated, objective short-range forecasts. Assessments will be performed at NCEP Service Centers and WFOs. Assessments will be done in parallel with field evaluation of GIFTS Derived Image Products.

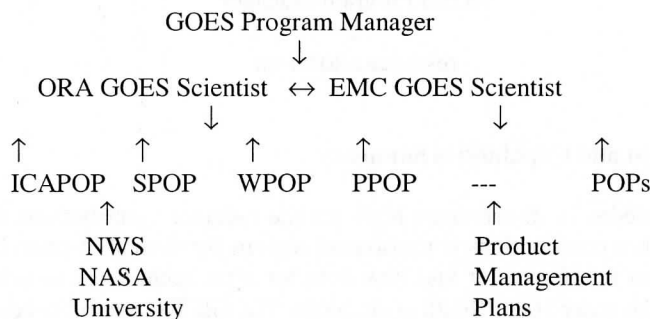
Budget estimates for these four activity areas follow. An ongoing activity is envisaged; the NWS portion will eventually become part of the GOES Product Assurance Program. Note that NWS costs are 105K/person year.
NWS-NCEP

FY	Task	5	6	7	8	Total	Comment	
2003		210	0	0	105	315	start work with GIFTS team	
2004		525	0	105	210	840	build assimilation tools	
2005		525	985	210	210	1930	CPU (880K), test assimilation	
2006		525	105	210	315	1155	conduct GIFTS demo	
2007		525	105	315	315	1260	perform assimilation tests	
2008		525	105	315	315	1260	redo assimilation tests	
2009		525	105	315	105	1050	GIFTS alg updates	

Total		3360	1405	1470	1575	7810		

APPENDIX B. Management Plan for Each Product

The management of all GIFTS Product Assessment 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 "NCEP GOES Scientist" are responsible to him to assure work is done, milestones met, and implementation accomplished. Finally, in the third tier, the Product Oversight Panels (POP) see to the maintenance and evolution of the products. The POPs report on progress at the monthly SPRBs and other venues, as requested by the GOES Program Manager. This management structure is depicted in the following diagram.



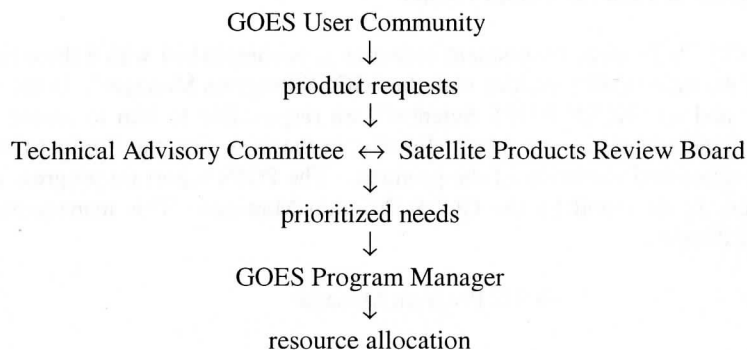
Steve Kirkner is the GOES Program Manager, Ralph Petersen is the NCEP GOES Scientist, and Paul Menzel is the ORA GOES Scientist. The POPs with their respective co-chairs (one from research and one from operations) are listed below.

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	?
Surface	B. Ramsey	S. Young
ERB	H. Jacobowitz	I. Guch
Calibration	M. Weinreb	C. Paris
Navigation	N. Pinkine	E. Harrod

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

Paul Menzel (co-chair)	NESDIS
Jim Gurka	NESDIS
Don Gray	NESDIS
Steve Koch	ERL
Leroy Spayd	NWS
Steve Lord	NWS
Greg Mandt	NWS
Ralph Petersen	NWS
Jim Purdom (co-chair)	NESDIS/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.



APPENDIX C. GIFTS Design and Capabilities Summary

Higher spectral resolution is needed to discriminate high altitude radiance contributions at opaque absorption line centers from low altitude radiance contributions at transparent regions between absorption lines. GIFTS responds to this need by using a Michelson interferometer and new detector array technology to achieve measurements with spectral resolution ($\lambda/\Delta\lambda$) on the order 1000 (Smith et al. 2000). The GIFTS spectral coverage is indicated in Figure C.1. This yields about 2000 spectrally independent measurements enabling much higher sounding vertical resolution and motion detection at more atmospheric levels. GIFTS will have temperature profile sensitivity in the short-wavelength side of the 15 micron CO₂ absorption band and moisture profile sensitivity in the short-wavelength side of the 6.3 micron H₂O absorption band.

The GIFTS vertical resolution and accuracy is expected to meet or come close to meeting the anticipated requirements (1 km vertical resolution with 1 degree Kelvin rms difference with respect to radiosondes) for global sounding for numerical weather prediction during the next decade (Smith, 1991). It will approach radiosonde quality in information content.

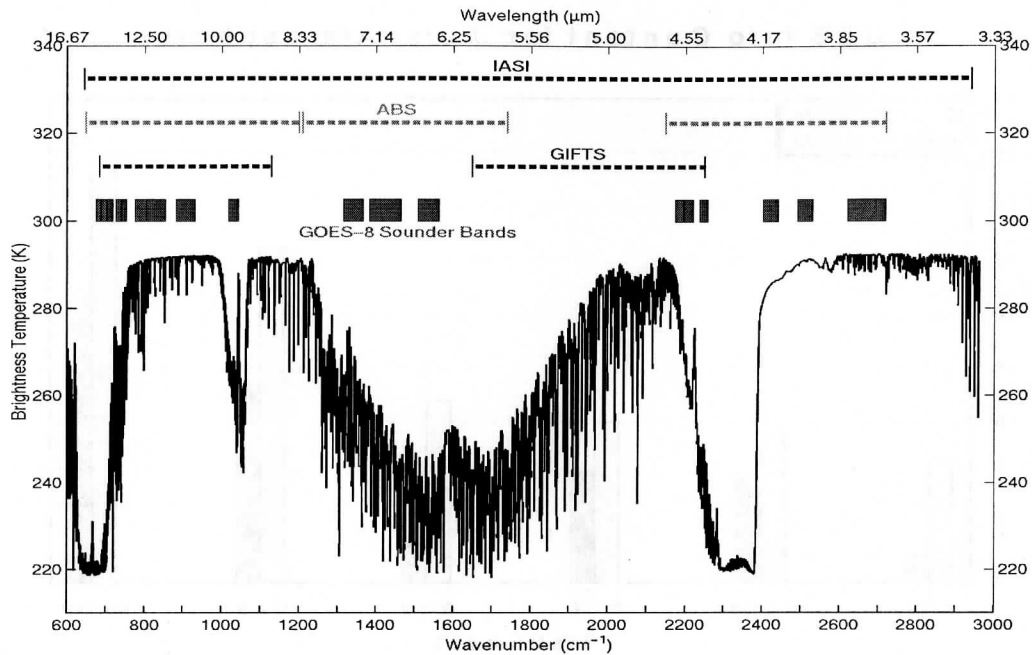


Figure C.1: GIFTS spectral coverage along with current GOES Sounder, IASI and the anticipated Advanced Baseline Sounder spectral coverages.

Figure C.2. demonstrates this last point. Information contents of various geostationary measurements past, present, and possibly future are compared to that of radiosondes. A global distribution of radiosonde data gathered by NOAA is used as the data base. Information content of the satellite measurements is estimated from the trace of the vertical resolution matrix, constructed from temperature and water vapor weighting functions, instrument noise, and forecast model error covariances (Huang and Purser, 1996). The VAS and GOES sounders represent past and current capabilities. G-18 represents the information content of the current 18 GOES spectral bands if they are narrowed to half wavenumber bandwidth. G-50 represents key parts of IR spectrum measured with 50 half wavenumber bands. The Geostationary Interferometer (or the GOES Atmospheric Sounder) covers the infrared spectrum from 4-15 micron with more than 2000 narrow spectral bands. RAOB is the mean information content from radiosonde measurements. The sample is chosen from atmospheric conditions in the tropics and mid-latitudes-summer; hence the moist atmosphere label. The present GOES 18 channel sounder possesses roughly 6 pieces of independent information about tropospheric temperature profiles and 4 about moisture. Enhancing the spectral resolution to half wave number or increasing the numbers of channels to 50 does not increase the information content appreciably. Only when the complete spectrum from 4 to 15 microns is sampled at high spectral resolution does the information content increase close to radiosonde quality.

The capability of a satellite borne interferometer to observe small scale atmospheric water vapor features has been investigated through the National Polar-Orbiting Environmental Satellite System (NPOESS) Aircraft Sounder Test-bed Interferometer (NAST-I) data. NAST-I has similar spectral and spatial measurement properties to the anticipated Geo-Interferometer. Figure C.3 displays the NAST-I high vertical resolution sounding capability; moist and dry layers of 1- to 2-km atmospheric depth are clearly resolved with the NAST-I system. This same vertical resolving power will be achieved with a Geo-Interferometer.

GOES Info Content for Moist Atmospheres

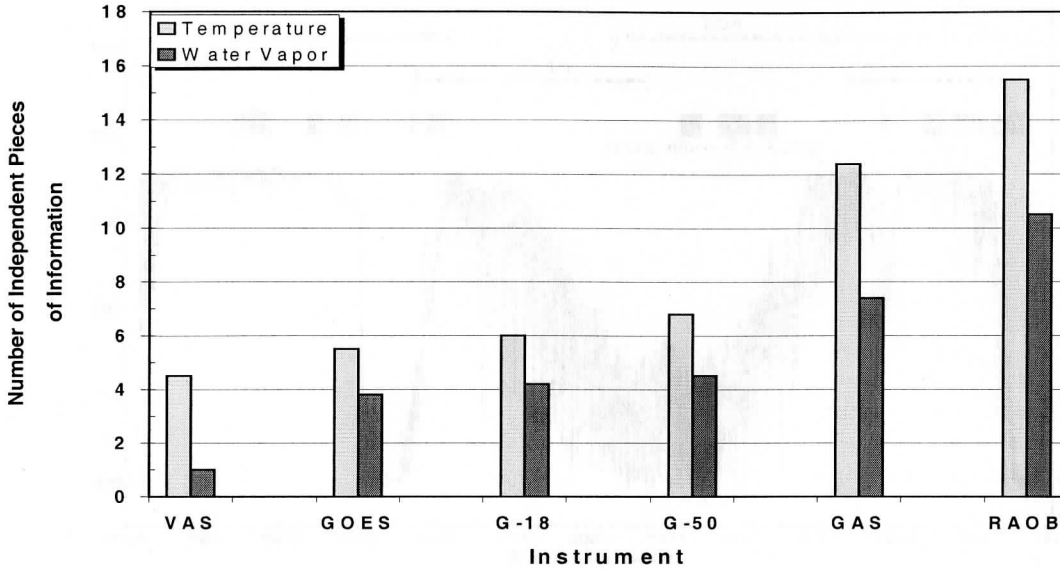


Figure C.2: Information content of geostationary measurements compared to that of radiosondes. VAS and GOES Sounder represent past and current capabilities. The remainder represent high spectral resolution capabilities. The Geo-interferometer (or Geostationary Atmospheric Sounder – GAS) capabilities come close to raob-like depiction of the atmospheric state.

GIFTS covers two spectral intervals of 14.6 to 8.8 microns (685 to 1130 cm^{-1}) and 6.0 to 4.4 microns (1650 to 2250 cm^{-1}) at high spectral resolution (how high depends on the mode of operation). More details about the system are available at <http://its.ssec.wisc.edu/~bormin/GIFTS/>. Table C.1 presents the areal coverage, temporal frequency, spectral resolution, and geophysical measurement for example modes of operation for GIFTS. Regional imaging achieves quasi-continuous imaging of localized areas and minute-interval imaging of large-scale areas. Global sounding gives full disk coverage every 7 minutes at contemporary sounder spectral resolutions (e.g., 18 cm^{-1}). High vertical resolution soundings and atmospheric chemistry measurements require 0.6 cm^{-1} spectral resolution and a longer signal integration time, thereby reducing the area coverage and/or frequency of observation relative to the imaging mode of operation. Nevertheless, GIFTS in the regional sounding mode can cover a major portion of the earth disk with high vertical resolution soundings in less than 0.5 hour. This feature is important for obtaining wind profiles from geostationary temperature and moisture sounding data (a simulation of these winds can be found in Figure C.4). GIFTS can achieve good simultaneity with earth orbiting satellite observations to enhance overall earth science objectives.

The expected sounding performance of GIFTS has been estimated by radiance simulations. The regional sounding mode simulations have produced rms tropospheric profile errors of less than 1.0 C in one km layer mean temperatures (averaging about 0.7 C in the troposphere) and around 15% in two km layer mean water vapor mixing ratios. The radiometric noise and accuracy requirements for this retrieval of temperature and water vapor in the regional sounding mode with 10 sec dwell time are: (1) noise equivalent radiance (NEN) in the longwave band (685 - 1130 cm^{-1}) less than $0.2\text{ mW/m}^2\text{ sr cm}^{-1}$, or about 0.1 K at 900 cm^{-1} at 300 K (2) NEN in the shortwave / midwave band (1650 - 2250 cm^{-1}) less than $0.06\text{ mW/m}^2\text{ sr cm}^{-1}$, or about 0.3 K at 1600 cm^{-1} at 250 K and (3) absolute calibration accuracy better than 1 K brightness temperature for earth scene brightness temperatures greater than 190 K for the longwave and greater than 240 K for the shortwave / midwave band.

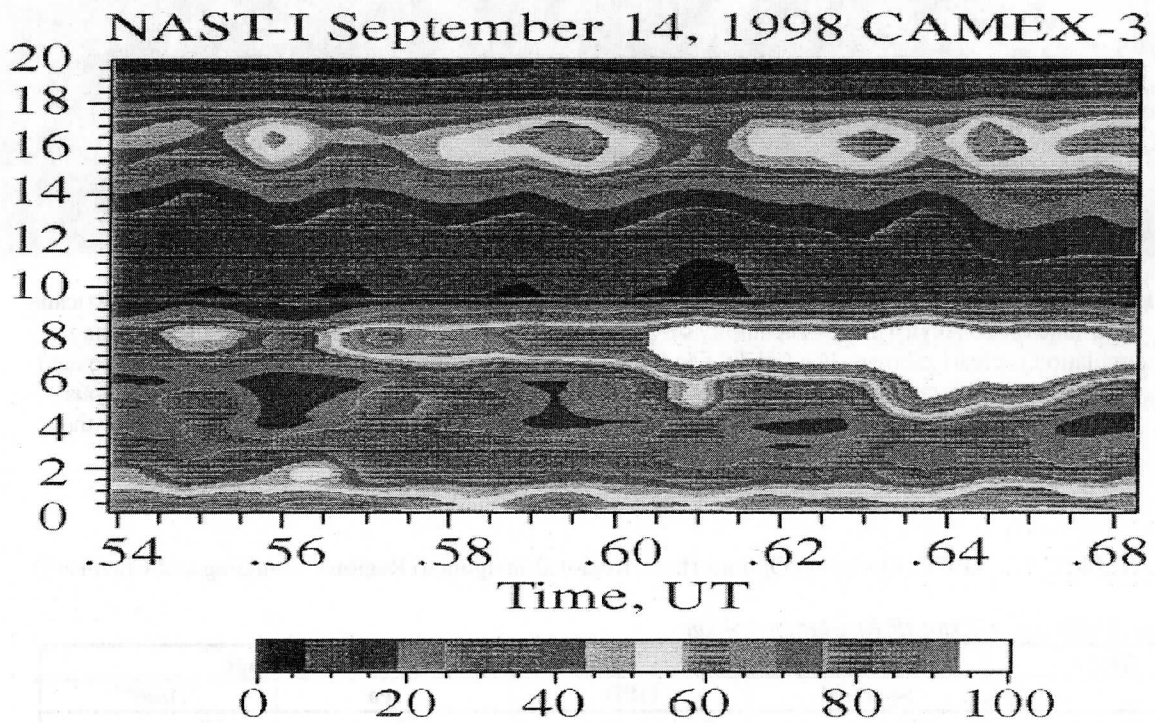
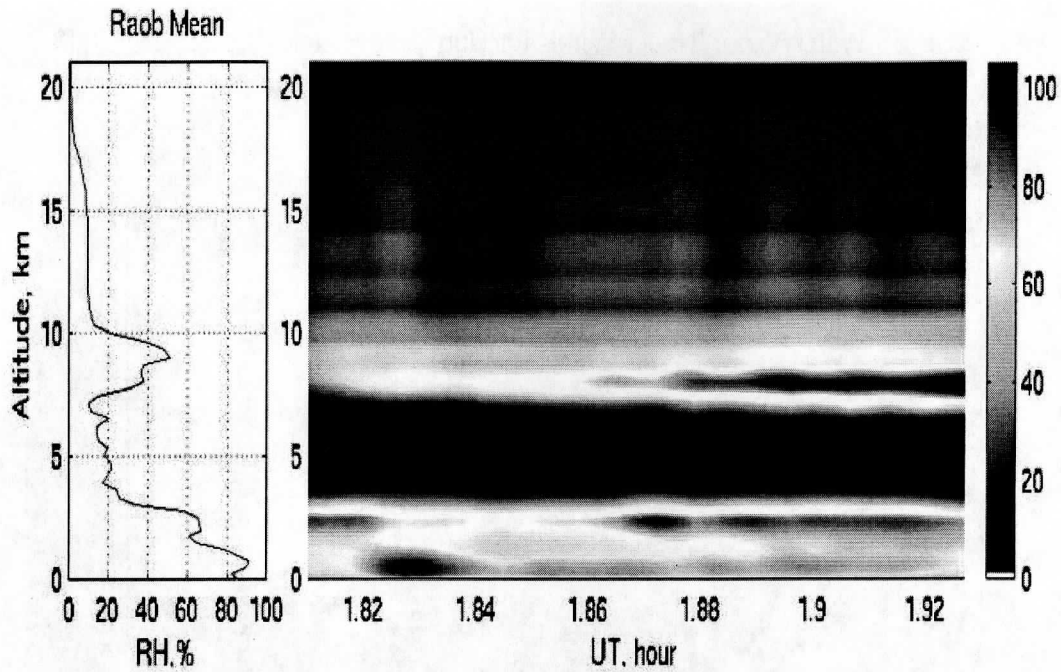


Figure C.3: Horizontal cross-section (75 km) of relative humidity derived from NAST-I radiances observed during two segments of a NASA ER-2 flight. (Top) The segment over Andros Island in the Bahamas on 14 September 1998 is shown together with the average of several radiosondes released during the aircraft overpass. (bottom) Another flight segment (125 km) is shown in color revealing the small scale moisture features.

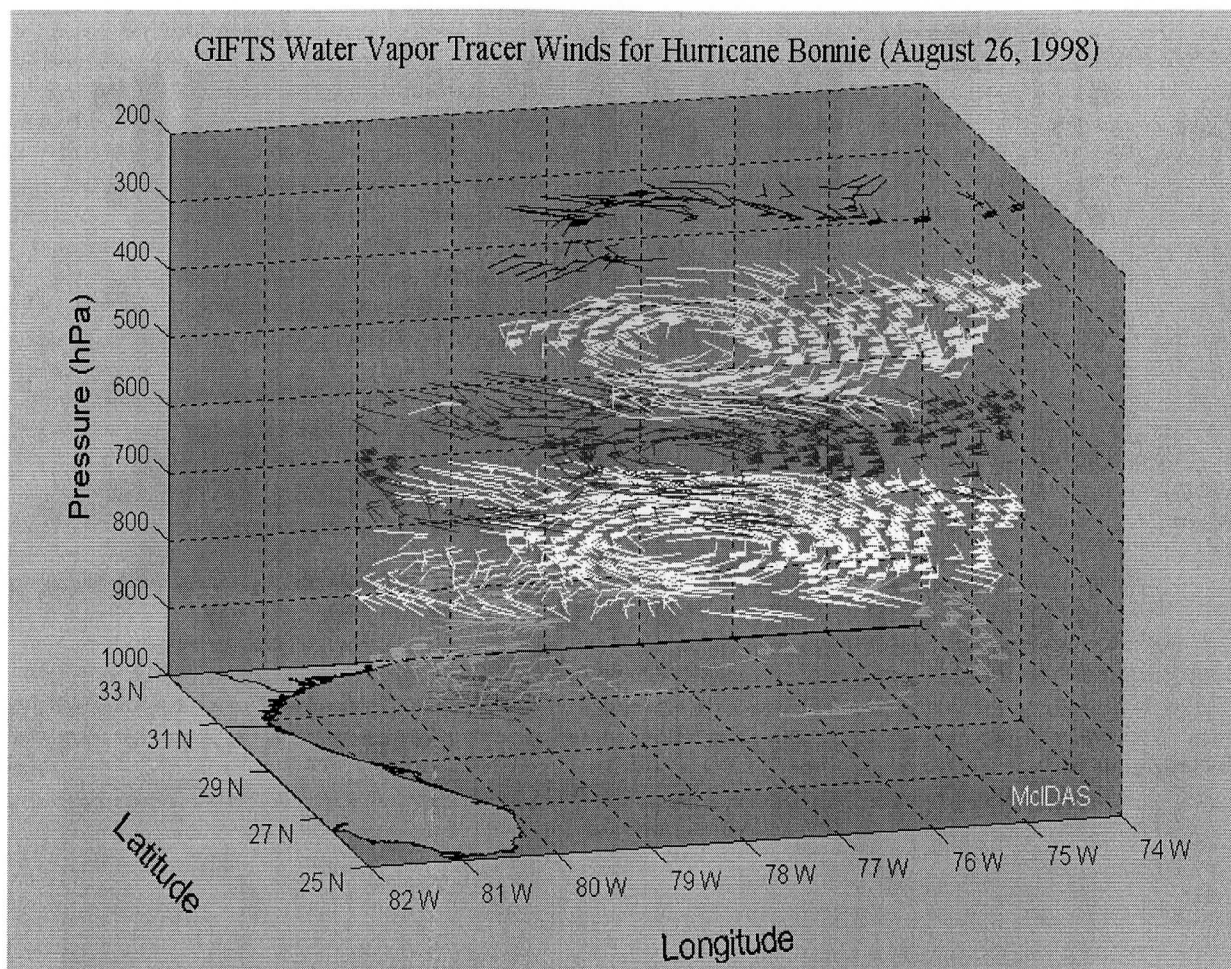


Figure C.4: Wind vectors derived from meso-scale model simulations of GIFTS radiances for Hurricane Bonnie on 26 August 1998. The ability of GIFTS to observe the vertical structure of the hurricane circulation is clearly shown. The GIFTS wind velocity errors will be much smaller than those associated with current geostationary satellite water vapor radiance tracer results as a result of the much higher vertical resolution of the GIFTS. The revolutionary aspect of GIFTS is that it provides access to the vertical dimension of the wind field, with accurate altitude assignment.

Table C.1: GIFTS Operating Options (from Regional Imaging to Regional Sounding and Chemistry)

Visible Resolution = 1 km; IR Resolution = 4 km

Mode	Resolution		Coverage	
	Spectral	OPD	Area	Time*
Stare Mode	0.3-36 cm ⁻¹	0.014-1.744 cm	512 km	<1-20 sec
Regional Imaging	36 cm ⁻¹	0.014 cm	6,000 km	3 min
Global Sounding	18 cm ⁻¹	0.027 cm	10,000 km	7 min
Regional Sounding and Chemistry	0.6 cm ⁻¹	0.872 cm	6,000 km	25 min

Assumes a constant data rate associated with a Michelson mirror scan velocity of 0.17cm/sec and 1 sec telescope step time.

APPENDIX D. References for further information on GIFTS and FTS and high spectral resolution interferometry

The CIMSS web site <http://cimss.ssec.wisc.edu/goes/abs/> contains a High Spectral Resolution FTIR Bibliography. The GIFTS instrument characteristics and capabilities are summarized at <http://danspc.larc.nasa.gov/GIFTS/>.

APPENDIX E. Acronyms

ABBA - Automated Biomass Burning Algorithm
ABI - Advanced Baseline Imager
ABS - Advanced Baseline Sounder
ACARS - Aeronautical Radio Incorporated Communications Addressing and Reporting System
AERI - Atmospheric Emitted Radiance Interferometer
AIREP - AIRcraft REPort
AIRS - Atmospheric Infrared Sounder
AMDAR - Aircraft Meteorological Data Relay
AMSU - Advanced Microwave Sounding Unit
ARAD - Atmospheric Research and Applications Division
ARM - Atmospheric Radiation Measurement (DOE)
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
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
CrIS - Cross track Infrared Sounder
CST - Convective Stratiform Technique
DMSP - Defense Military Satellite Program
DOE - Department of Energy
DON - Department of the Navy
DPI - Derived Product Image
EDAS - Eta Data Assimilation System
EMC - Environmental Modeling Center
EOS - Earth Observing System
ERBE - Earth Radiation Budget Experiment
ERB - Earth Radiation Budget Satellite
ERL - Environmental Research Laboratory
ESA - European Space Agency
EUMETSAT - European organization for the exploitation for METeorological SATellites
FAA - Federal Aviation Administration
FPA - Focal Plane Arrays
FPDT - Forecast Products Development Team (ORA)
FSL - Forecast Systems Laboratory of ERL
FTS - Fourier Transform Spectrometer

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
GIFTS – Geostationary Imaging Fourier Transform Spectrometer
GMS - Geostationary Meteorological Satellite (Japan)
GOES - Geostationary Operational Environmental Satellite
GPS – Global Positioning System
GSFC - Goddard Space Flight Center
GWEX – Global Energy and Water Cycle Experiment
HIRS - High resolution Infrared Radiation Sounder
HIS - High spectral resolution Interferometer Sounder
HPC - Hydrometeorological Prediction Center
HT – Hydrology Team (ORA)
IASI - Infrared Atmospheric Sounding Interferometer
IFFA - Interactive Flash Flood Analyzer
INR - Image Navigation and Registration
IRIS - Infrared Radiation Interferometer Spectrometer
ISCCP - International Satellite Cloud Climatology Project
LAPS - Local Area Prediction System
M-AERI - Marine AERI
MDCRS – Meteorological Data Collection and Reporting System
METEOSAT - METEOrological SATellite
METOP - Meteorological Operational Platform
MIMR - Multifrequency Imaging Microwave Radiometer
MISR - Multi-angle Imaging Spectro-Radiometer
MODIS – Moderate resolution Imaging Spectroradiometer
MSFC - Marshall Space Flight Center
MTF - modulation transfer function
MTSAT - Multi-functional Transport Satellite
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
NMP – New Millennium Program
NOAA - National Oceanic and Atmospheric Administration
NORPEX – Northern Pacific Experiment
NOVA - NOAA Operational VAS Assessment
NPOESS - National Polar-orbiting Operational Environmental Satellite System
NWS - National Weather Service
NWSTC - National Weather Service Training Center
OAR - Office of Oceanic and Atmospheric Research
OGE - Operational Ground Equipment
ORA - Office of Research and Applications
ORAD – Ocean Research and Development Division
OSD – Office of Systems Development
OSDPD - Office of Satellite Data Processing and Distribution
POP - Product Oversight Panel
QI - Quality Indicator
QPF – Quantitative Precipitation Forecast
RAMMT - Regional and Mesoscale Meteorology Team (ORA)

RAMSDIS - Regional and Mesoscale Meteorology Branch Advanced Meteorological Satellite
Demonstration and Interpretation System

RDAS - Regional Data Assimilation System

RFF – Recursive Filter Flag

RUC – Rapid Update Cycle

SAB – Synoptic Analysis Branch (OSDPD)

SAO - Systems Acquisition Office

SCP – Satellite Cloud Product

SOCC - Satellite Operations Control Center

SOO - Science Operations Officers

SPC - Storm Prediction Center

SPOP - Sounding Product Oversight Panel

SPOT - Systeme Probatoire d’Observation de la Terre satellite

SPSRB - Satellite Products and Services Review Board

SSMI - Special Sensor Microwave/Imager

SSMT - Special Sensor Microwave/Temperature

SST - Sea Surface Temperature

SSU - Stratospheric Sounding Unit

TAC – Technical Advisory Committee

THORPEX - The Hemispheric Observing System Research and Predictability Experiment

TIROS - Television InfraRed Operational Satellite

TOA - Top of the Atmosphere

TOMS - Total Ozone Mapping Spectrometer

TOVS - TIROS Operational Vertical Sounder

TPC - Tropical Prediction Center

TRMM - Tropical Rainfall Measuring Mission

VAS - VISSR Atmospheric Sounder

VDUC - VAS Data Utilization Center

VIIRS - Visible Infrared Imager Radiometer Suite

VISSR - Visible and Infrared Spin Scan Radiometer

WSFO - Weather Service Forecast Office

WVSS – Water Vapor Sensing System