**P5.8** MEASUREMENT CONCEPT VALIDATION PLANS FOR GIFTS

Dave Tobin*, Chris Velden
Space Science and Engineering Center, University of Wisconsin-Madison

Nikita Pougatchev, William Smith
NASA Langley Research Center

## 1. Introduction

The Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) Indian Ocean METOC Imager (IOMI) is a combined NASA New Millennium Program, NOAA, and U.S. Navy mission. It represents a revolutionary step in satellite based remote sensing of atmospheric parameters. Using the combination of a Fourier Transform Spectrometer and Large Area Focal Plane Arrays, GIFTS will measure the Earth emitted infrared radiance at the top of atmosphere from geosynchronous orbit with an unprecedented combination of spectral, temporal, and spatial resolution and coverage. In its nominal Regional Sounding and Chemistry mode, GIFTS will measure the infrared spectrum in two bands (14.6 to 8.8 μm, 6.0 to 4.4 μm) at a spectral resolution of ~0.6 $cm^{-1}$ for a 128 × 128 set of ~4-km footprints (a ~512 × 512 km area) every 11 seconds. The instrument will have the capability of taking successive measurements of such data to scan desired regions of the globe, and tradeoffs in the desired spectral resolution and spatial and temporal sampling can be performed. From these measurements, thermal and gaseous concentration profiles, cloud properties, wind field profiles, and numerous derived products can be retrieved.

Following launch in CY 2005, GIFTS will be positioned over or near the Continental United States for 12 to 18 months, and will then attain a position over the Indian Ocean for NAVY operations. This poster presents an overview of a "Measurement Concept Validation Plan" (MCVP), which describes the various tasks and data sources associated with the validation of the GIFTS Measurement Concept Objectives (see Section 2) under the scope of NASA's New Millennium Program (NMP) Earth Observing 3 (EO3) Mission. The goal of the resulting Measurement Concept Validation activities to occur while the sensor is stationed over CONUS is an accurate and timely assessment of the instrument performance and accuracies of the core GIFTS products for a representative set of observation conditions. In particular, this plan addresses validation in the areas of navigated and calibrated high spectral resolution radiances, temperature and water vapor profile retrievals, wind retrievals, carbon monoxide and ozone concentration retrievals, cloud property retrievals, and data compression.

While the NMP EO3 GIFTS program is primarily a technology validation program, the GIFTS Primary Measurement Concept Objective provides 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. The goal of the MCVP is to define the various tasks and data sets that will be used to assess whether the desired accuracies in the primary GIFTS products are being attained. The plan therefore plays a critical role in the NASA NMP portion of the mission, detailing the various data to be collected, processed, and analyzed in order to validate the performance of the instrument and accuracy of the resulting products.

* *Corresponding author address:* Dave Tobin, CIMSS/SSEC University of Wisconsin-Madison, Madison, WI 53706; email: dave.tobin@ssec.wisc.edu

## 2. GIFTS Measurement Concept Objectives

The GIFTS Measurement Concept Objectives are divided into three groups: Primary, Secondary, and Applications Objectives. The Primary objective establishes the baseline instrument performance and operational requirements. The Secondary objectives fall within the measurement capability of the baseline GIFTS instrument and are considered a secondary priority with respect to mission operations and validation activities. The Applications objectives fall outside the scope of the funded NMP EO3 mission, require participation by organizations outside NMP, and as such are dependent upon funding by NASA, NOAA, or other organizations following the completion of the NMP technology and measurement concept validation.

For GIFTS, the Primary Measurement Concept Objective is to provide frequent, high spatial resolution temperature and water vapor sounding, allowing the vertical profile of wind velocity to be obtained by tracing the horizontal displacement of water vapor and cloud features. The Secondary objectives are to a) provide time-dependent ozone and carbon monoxide concentrations within layers of the troposphere and stratosphere, and b) to provide high temporal resolution measurements of radiative properties of clouds (augmented by a higher spatial resolution visible low-light-level camera to provide quasi-continuous imaging). The Applications objectives of GIFTS are numerous and are to a) enable demonstration of improvements in weather and climate observation, analysis and prediction, b) add to knowledge of the global water cycle and supporting research contributing to risk reduction from intense weather disasters, c) demonstrate the benefit to the commercial airline industry by using GIFTS data for better weather hazards forecasting that can reduce the risk to safe flight, as well as to reduce fuel costs through improved flight management as a result of increased availability of wind

data, and d) provide measurements that enhance other new Earth systems scientific investigations, especially the EOS Aqua and Aura and Earth Systems Science Pathfinder missions.

Various instrument parameters, geophysical products, and their required accuracies that are described in the EO-3 Mission Requirements Document (EMRD), the GIFTS-IOMI Mission Systems Requirements Document (GMSRD), and the GIFTS Instrument Requirements Document (GIRD). Tables 1 and 2 highlight the parameters and accuracies most relevant the MCVP efforts.

Under the scope of the NMP Measurement Concept Validation, this plan addresses the basic validation of the core GIFTS products relevant to the Primary Measurement Concept Objective as given above. This includes the validation of a) the navigation of the radiance data to Earth located geographic footprints, b) the spectral, radiometric, and spatial accuracy of the measured radiance spectra, c) the retrieved temperature and water vapor profiles, d) the retrieved wind fields, and e) the accuracy of the compressed data stream. These areas are chosen due to their direct relevance to the Primary Measurement Concept Objective; the navigation accuracy has a direct impact on the retrieved winds, the accuracy of the measured radiances impacts directly on the retrieved temperature, water vapor and resulting wind profiles, and the data compression assessment is relevant to the ability to perform such soundings operationally. This plan also addresses validation of the Secondary Measurement Concept Objectives regarding carbon monoxide and ozone concentrations and cloud properties.

## 3. Measurement Concept Validation Plans

The MCVP draws upon experience gained through previous and ongoing validation efforts of geostationary and polar orbiting (e.g. GOES, HIRS, IMG, AIRS, CrIS) and aircraft based (HIS, NAST-I, S-HIS) sounders. The plans also draw upon numerous advances in the instrumentation required for obtaining high quality validation data, as well as advances in the characterization of the accuracy of existing, traditional sources of validation data. In addition, due to the non-operational aspect of the NMP GIFTS mission, the validation will benefit from being able to influence, and in some cases, dictate the orbital positioning of the GIFTS satellite during the first 12 to 18 months in orbit. Additionally, specific observation sequences and spectral/temporal/spatial tradeoffs can be tailored for the purpose of validation.

The validation approaches are focused on comparisons of the GIFTS products to selected high quality validation data for GIFTS product accuracy assessment. A simple 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. The approaches include comparisons to data from ground based networks and high quality validation sites (e.g. ARM CART, Wind Profiler network), airborne observation networks (e.g. ACARS), other satellite based radiance sensors (e.g. AIRS, IASI) and retrievals (e.g. MOPITT, TES, AIRS), and data collected as part of a dedicated field campaign. While external data is the primary tool of these efforts, some validation can be performed using GIFTS data alone. This includes internal checks such as blackbody view analyses and specific pointing exercises. 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.

For the majority of this effort, the desired validation data are available from routine operations and as such do not require special arrangements for performing and/or obtaining the measurements. A notable exception are plans for a dedicated air and ground based field campaign in the Oklahoma ARM site domain approximately 4 months after launch.

Specific validation activities are planned for each validation area (navigation, radiance, temperature, water vapor, winds, carbon monoxide, ozone, cloud properties, and data compression). These approaches, the orbital geolocations and viewing sequences required to collect the appropriate data, and the analysis techniques are contained in the MCVP, and will be presented in detail at the poster presented at the conference.

## 4. Summary, and Other GIFTS Validation Efforts and Opportunities

The GIFTS Measurement Concept Validation Plan (MCVP) presents plans for assessing the basic instrument performance and product accuracy of GIFTS following the year after launch, under the scope of NASA's NMP EO3 mission. Details of this plan will be presented at the conference. As defined by the focus of the NMP program and its concentration on technology development and validation, the NMP funded efforts of the Measurement Concept Objectives validation are limited in scope. Generally, the NMP efforts will not require a relatively large percentage of the overall GIFTS data volume and are not intended to replace or duplicate additional efforts, which are more related to operational applications and use of the data. Rather, the NMP efforts are targeted in scope to provide enough data and analysis for a timely post-launch assessment of the accuracy of the core GIFTS products for a representative set of observation conditions. These efforts will occur during the first twelve months after launch while GIFTS is stationed in various positions over or near the continental United States.

These NMP MCV efforts will be supplemented by NOAA participation in the GIFTS program. This effort, the NOAA Demonstration of Operational Utility, will

| Measurement Concept Objective | Parameter | Measurement Uncertainty (rms) | Reference |
|---|---|---|---|
| **Primary Objective 1:** Atmospheric profiles | Temperature | = 1 K for 1-km layers | EMRD, EO76 |
| | Water vapor | = 20% for 2-km layers | EMRD, EO76 |
| | Wind velocity | = 3 m/s for 2-km layers | EMRD, EO76 |
| **Secondary Objective 1:** Ozone and Carbon monoxide concentrations | $O_3$ concentration | 10-20% for 6-km mid-tropospheric layers<br>10-20% for three 6-11 km stratospheric layers | EMRD, EO68 |
| | CO concentration | 10-20% for three 3-8 km tropospheric layers | EMRD, EO68 |
| **Secondary Objective 2:** Cloud Properties | Cloud mask | Cloud or clear, 3% | EMRD, EO68 |
| | Cloud top height | 20 mbar (pressure altitude) | EMRD, EO68 |
| | Cloud top temperature | = 2 K | EMRD, EO68 |
| | Cloud emissivity | 10% | EMRD, EO68 |
| | Cloud top phase | Ice or water, 10% | EMRD, EO68 |

Table 1. Level 2 product accuracy goals for the Regional Sounding and Chemistry (0.6 $cm^{-1}$) mode.

| Parameter | Measurement Uncertainty | Reference |
|---|---|---|
| Radiometric Calibration | | |
| Absolute | = 1.0 K (3σ) for $T_{scene}$ = 190 K (LW) | GMSRD, MR595 |
| | = 1.0 K (3σ) for $T_{scene}$ = 240 K (SMW) | GMSRD, MR595 |
| Reproducibility | = 0.2 K (3σ) for $T_{scene}$=190 K (LW) over 1 day | GMSRD, MR597 |
| | = 0.2 K (3σ) for $T_{scene}$=240 K (LW) over 1 day | GMSRD, MR597 |
| Radiometric Noise, NEN | = 0.2 mW/($m^2$ sr $cm^{-1}$) (1σ) for $T_{scene}$ = 280 K (LW) | GMSRD, MR586 |
| | = 0.06 mW/($m^2$ sr $cm^{-1}$) (1σ) for $T_{scene}$ =280 K (SMW) | GMSRD, MR261 |
| Spectral Calibration | | |
| Knowledge | = 5 parts in $10^6$ (3σ) | GMSRD, MR599 |
| Reproducibility | = 1 part in $10^6$ (3σ) over 30 days | GMSRD, MR608 |
| Pointing | | |
| Frame-to-Frame Pointing Knowledge | = 25 μrad over a 1 hour period | GMSRD, MR505 |
| Pointing Stability | = 11.2 μrad (1s) | GMSRD, MR511 |
| Pointing Jitter | = 11.2 μrad (1s) | GMSRD, MR512 |
| Geolocation Knowledge | = 1 km at nadir | GMSRD, MR506 |
| Geolocation Pointing Accuracy | = 50 km | GMSRD, MR513 |
| Channel-to-Channel Knowledge | = 11.2 μrad (1s) | GMSRD, MR583 |

Table 2. Selected Level 1 product accuracy objectives for the Regional Sounding and Chemistry (0.6 $cm^{-1}$) mode.

nominally take place 6 months after launch to 18 months after launch. These efforts are similar to the NMP Measurement Concept Validation efforts but are distinguished by the larger scope and data volume associated with operational or quasi-operational use of the GIFTS data. Along with traditional validation (e.g. comparison with in-situ sensors) 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 also plays a role in determining the desired orbital positions and resulting geographical areas and meteorological conditions observed by GIFTS. Details of these efforts are given in the *NOAA GIFTS Product Assurance Plan*.

Additionally, the NMP and NOAA validation efforts are expected to be supplemented by a solicitation for

proposals and resulting funding for further validation and algorithm development of the scientific products and goals of GIFTS. Specifically, this would provide additional funding for the Secondary and Applications Objectives Validation, as well as further validation of the Primary Objectives.

## 5. Acknowledgements

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## 6. References

1. GIFTS Measurement Concept Validation Plan (MCVP, GIFTS-02-002).
2. EO-3 Mission Requirements Document (EMRD, GIFTS-01-002).
3. IOMI Mission Requirements Document (IMRD, GIFTS-01-003).
4. GIFTS-IOMI Mission System Requirements Document (GMSRD, GIFTS-01-008).
5. GIFTS Instrument Requirements Document (GIRD, GIFTS-04-001).
6. NOAA GIFTS Product Assurance Plan (GPAP)