

## **PREPARATIONS FOR THE GEOSYNCHRONOUS IMAGING FOURIER TRANSFORM SPECTROMETER**

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### **INTRODUCTION**

The Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) will be completed in late 2005, to support a 2006 or later launch. The GIFTS will be orbited as part of NASA's New Millennium Program Earth Observing-3 (EO-3) Mission and will serve as a prototype of sounding systems to fly on future operational geostationary satellites.

The first year of operation of GIFTS will support the infusion of new technologies and data processing techniques into future geostationary operational satellite systems and ensure their timely exploitation in numerical weather prediction (NWP). The mission will validate the GIFTS measurement concept for altitude-resolved (water vapour observation based) winds. The GIFTS will result in high temporal and spatial resolution soundings of the atmosphere for temperature and absorbing species such as water vapour and ozone, and demonstrate new technologies for future research and operational systems.

We note some of the development activity in support the application of GIFTS data over continental USA and also note preparation for the collection and utilisation of this data when the GIFTS is stationed over its permanent position which is dependent upon the satellite mission of which GIFTS is part. The development activity includes preparation for providing; radiance products for NWP, altitude resolved, error characterised winds, temperature and moisture profiles, product imagery (stability fields, water vapour fields, etc.), sea and land surface temperatures with attendant emissivities, ozone and CO amounts and cloud properties. The development activity has included use of aircraft ultra spectral observations, AIRS (Advanced Infrared Sounder) data, and also synthetic GIFTS data. Overall, it is clear that the program indicates significant potential benefit from the high temporal, spectral and spatial resolution ultra spectral observations provided by this instrument and supports further preparation for their exploitation.

### **2. BACKGROUND**

The GIFTS (Smith et al. 2001) was selected for NASA's New Millennium Program (NMP) Earth Observing-3 (EO-3) mission in 2000. The GIFTS combines emerging sensor and data processing technologies to make geophysical measurements that will contribute to earth system science and lead to significant improvements in meteorological observation and forecasting. The mission will demonstrate revolutionary technologies for future research and operational systems and will validate the measurement concept of water vapour observation based altitude-resolved winds. The use of GIFTS technologies in operational instrumentation

is vital for optimizing the next generation of geostationary weather and climate observing systems.

The first year of operation of GIFTS is particularly important for supporting the infusion of GIFTS technology and data processing techniques into the future operational GOES-R system. After a validation and demonstration phase over continental USA, it is planned to transfer the GIFTS operation to a permanent location dependent upon the specific satellite mission selected for the GIFTS. The intent is to use the GIFTS data for Earth Observing System (EOS) scientific research and also for operational weather forecasting as a component of the Global Observing System (GOS).

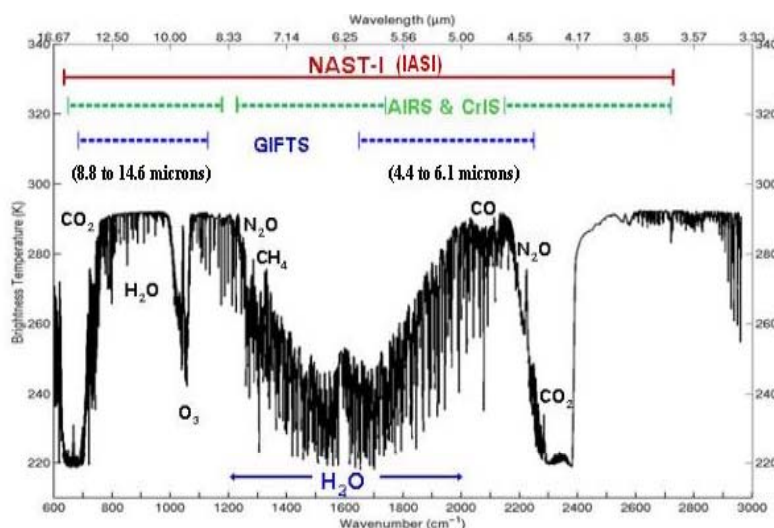
### **3. THE GIFTS EO-3 MISSION**

The GIFTS New Millennium Program Earth Observing-3 (EO-3) satellite mission will allow advanced technologies to observe surface thermal properties, and atmospheric weather and chemistry variables in four dimensions. Focal plane detector arrays, combined with a Fourier Transform Spectrometer will enable atmospheric radiance spectra from many fields of view to be observed simultaneously at the detector elements, thereby providing high horizontal, vertical and temporal resolution temperature and moisture sounding information. The temporal resolution will be provided by the geosynchronous satellite platform, which allows near continuous imaging of the atmosphere's three-dimensional structure.

The GIFTS instrument will be completed, tested, and launch ready by the end of 2005. There is currently considerable effort being devoted to identifying a spacecraft opportunity for a 2006-2009 launch, possibly through the US Air Force space test program. After the validation and demonstration phase over continental USA, the GIFTS will be moved to its permanent location, dependent upon the specific space mission chosen for the GIFTS, to continue its Earth Observing System role as part of the GOS. The GIFTS permanent location may be over the Indian Ocean, as originally planned, or for example the western Pacific Ocean. The Australian Bureau of Meteorology has already undertaken planning and development activity to support GIFTS data acquisition, processing, distribution, application and archival for such an eastern hemisphere satellite position.

### **4. THE INSTRUMENT AND MEASUREMENTS**

All of the new GIFTS technologies are now developed, being tested and meeting or exceeding requirements. The GIFTS uses large area format focal plane array (LFPA) infrared (IR) detectors ( $128 \times 128$ ) in a Fourier Transform Spectrometer (FTS) mounted on a geosynchronous satellite to gather high-spectral resolution ( $0.6 \text{ cm}^{-1}$ ) and high-spatial resolution (4-km footprint) infrared radiance spectra over a large geographical area ( $512 \text{ km} \times 512 \text{ km}$ ) of the Earth in a 10-second time interval. Extended Earth coverage is achieved by step scanning the instrument viewing area in a contiguous fashion. The radiance spectra observed at each time step (see Fig. 1) can be used to infer high vertical



**Figure 1. The NAST-I spectral coverage compared to that of advanced satellite sounders.**

resolution (1 - 2 km) temperature and water vapour mixing ratio profiles. These profiles are obtained on a 4-km grid and may be converted to relative humidity profiles. Images of the horizontal distribution of relative humidity for atmospheric levels, vertically separated by approximately 2 km, can be constructed for each spatial scan. Successive images of clouds and the relative humidity for each atmospheric level can then be used to reveal the motion of small-scale thermodynamic features of the atmosphere, providing a measure of the wind velocity distribution as a function of altitude. The net result is a dense grid of temperature, moisture, and wind profiles which can be used for atmospheric analyses and operational weather prediction. Ozone ( $O_3$ ) and carbon monoxide (CO) features observed through their spectral radiance signatures provide a measure of the transport of these pollutant and greenhouse gases.

## 5. PRODUCTS

Programs are now well underway to develop products for the validation, demonstration and extended operational phases of the GIFTS EO-3 mission. The products include :

- Radiance products (selected channels, superchannels, eigenvectors),
- Altitude-resolved winds
- Water vapour (soundings, fluxes, winds),
- Temperature (soundings, stability),
- Carbon monoxide concentration (2 Layers),
- Ozone concentration (4 Layers),
- Surface Temperature and emissivity,
- Clouds (altitude, optical depth, microphysical properties, winds),
- Mineral Dust / Aerosol Concentration and Visibility.

These applications are under test, supported by well-advanced development programs.

## 6. A PRODUCT EXAMPLE – ALTITUDE-RESOLVED WINDS

A key measurement concept associated with GIFTS is high spatial and temporal resolution altitude resolved winds. These winds represent an important product to be produced by the GIFTS. Work to date on this application has used both synthetic data and airborne interferometer observations. Here, we note recent work based on airborne interferometer data taken in association with THORPEX (THE Observing system Research and Predictability EXperiment). The data was collected by the NAST-I (National Polar-orbiting Operational Environmental Satellite System (NPOESS) Airborne Sounding Testbed-Interferometer) instrument flown aboard a NASA ER-2 aircraft. The NAST-I is described below.

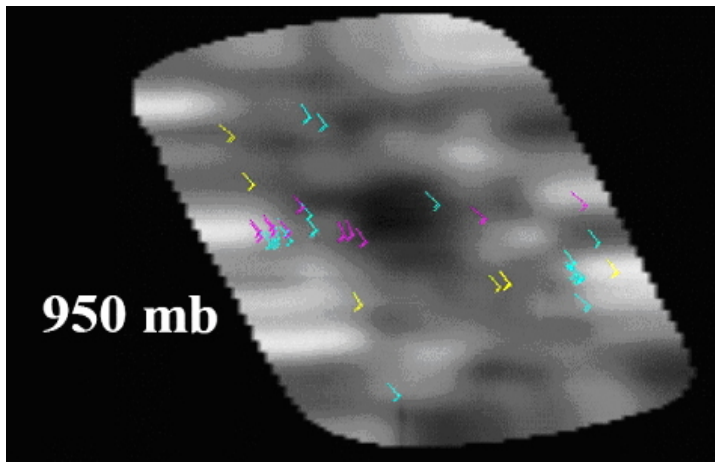
### 6.1 The NAST-I Instrument

The NAST-I (Smith et al. 1999) was developed by the NPOESS Integrated Program Office (IPO) to be flown on high altitude aircraft and provide the experimental observations needed for finalizing specifications and testing proposed designs and data processing algorithms for the Cross-track Infrared Sounder (CrIS) and for the GIFTS. The NAST-I has a spectral range of 3.6–16.1  $\mu\text{m}$ , without gaps (See Fig. 1) and covers the spectral ranges and resolutions of current and planned advanced high spectral resolution infrared spectrometers to fly on polar orbiting and geostationary weather satellites. These include the EOS-AIRS (Advanced Infrared Sounder), METOP-IASI (Infrared Atmospheric Sounding Interferometer), the NPP (NPOESS Preparatory Project)/NPOESS-CrIS (Cross-track Infrared Sounder), and the EO-3/GIFTS. The NAST-I spectral resolution is equal to, in the case of IASI, or higher than all current and planned advanced sounding instruments. Hence, the NAST-I data can be used to simulate the radiometric observations to be achieved from these advanced sounding instruments. Moreover, the forward radiative transfer models and product retrieval algorithms planned for these satellite systems can be validated prior to launch. The NAST-I can also be used for the vital purpose of post-launch calibration and validation of sensors and data products for the advanced satellite sounding systems.

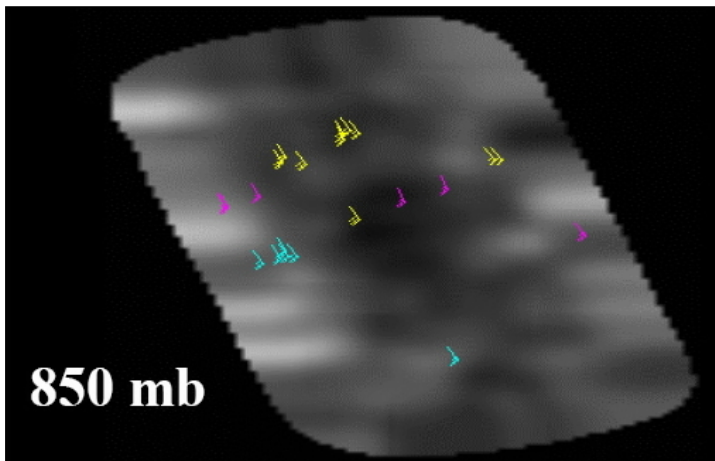
The NAST-I spatially scans the Earth and atmosphere from an aircraft, such as the high-altitude NASA ER-2 research aircraft. From an altitude of 20 km, 2.6 km spatial resolution and a 46 km swath width can be achieved, thereby providing three-dimensional hyperspectral images of radiance ( $x, y, v$ ) and derived geophysical products. Sequential aircraft over flights can provide a fourth dimension, time.

### 6.2 Altitude-resolved Winds

In February 2003, the THORPEX field experiment west of the California coast was instrumental in providing data to allow generation and validation of water vapour tracer wind profiles generated from consecutive NAST-I multi-frequency images. The data was from a NASA ER-2 flight on 11 February 2003 and the method used for determination of the atmospheric water vapour concentration was the eigenvector method of Smith and Wolf (1976), (Zhou et al. (2002)). The winds were subsequently generated from consecutive single pressure level relative humidity images using an automatic tracking program, developed at the University of Wisconsin. The winds at 950 and 850 hPa are shown in Fig. 2.

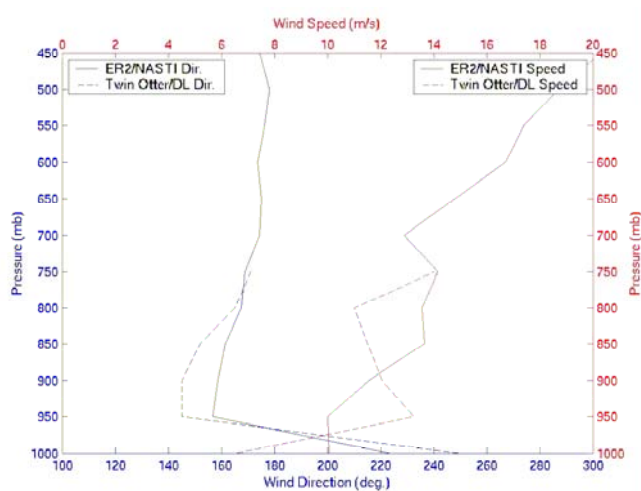


**Fig. 2 (a) Automated NAST Water Vapour Profile Tracer Winds at 950 mb**



**Fig. 2 (b) As in Fig. 2 (a) but at 850 mb**

The automated NAST-I water vapour profile tracer winds showed good time and space continuity. A comparison of the NAST-I winds with those measured by Twin Otter Doppler LIDAR is shown in Fig. 3. The profiles indicated differences generally less than 3 m/s.



**Fig. 3 A comparison of collocated, contemporaneous winds from NAST-I water vapour observations and NOAA measurements near 35° N, 121° W on 11 February 2003**

This study has also been complemented by earlier work using airborne advanced sounder observations taken during the CAMEX experiment in September 1998. In that study, sequential NAST-I based water vapour and temperature retrievals were used with 4D-VAR (Bennett et al. 1996) in a study to demonstrate the influence of these data on the assimilated wind field (Leslie et al. 2002, Le Marshall et al. 2003).

The application of winds generated directly from multi-frequency imagery to NWP has also been investigated. The error characterisation of atmospheric motion vectors, including the estimation of their expected error, and their application to NWP, is reported in Le Marshall et al. (2004a, 2004b). The accurate error characterisation of GIFTS based AMVs is considered an important part of this development activity.

## 7. SUMMARY

All the new technologies required for GIFTS are developed and under test. They are meeting or exceeding mission requirements. The instrument is expected to be completed, tested and launch-ready by the end of 2005. A spacecraft opportunity for a 2006 – 2009 launch is currently being identified. Development work supporting the effective exploitation of GIFTS data is well advanced and shows the significant potential benefit from the instrument.

The validation phase over the first eighteen months involves data delivery to NASA, NOAA, the US Navy and the UW CIMSS for operational utility demonstration and a comprehensive validation process. Movement of the GIFTS to a permanent location for the extended operations phase of the mission could benefit greatly from reception, data processing and product generation at a ground station in the Eastern Hemisphere region such as Australia. Planning for such an involvement has been undertaken in the Australian Bureau of Meteorology and development work related to product generation is already underway.

## 8. ACKNOWLEDGEMENTS.

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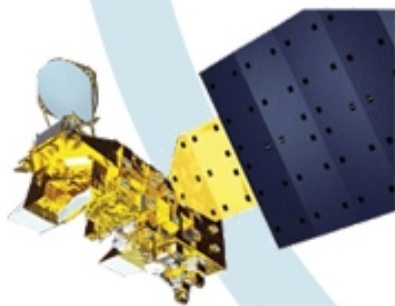
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