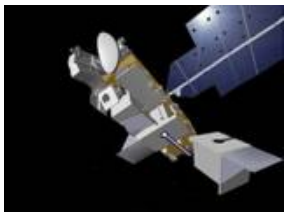
Tropospheric Emission Spectrometer (TES) Langley ASDC Project Guide



Summary:

The Tropospheric Emission Spectrometer (TES) is an imaging infrared Fourier-transform spectrometer in polar Sun-synchronous orbit aboard the Earth Observing System's Aura satellite, launched on July 15, 2004. TES will gather data on the global distribution of tropospheric ozone and of the physical and chemical factors that control its formation, destruction, and distribution. This data will be used to create a three-dimensional model depicting tropospheric chemistry, troposphere-biosphere interactions, and troposphere-stratosphere exchanges.

TES was built for NASA by the Jet Propulsion Laboratory, California Institute of Technology in Pasadena, California. A detailed description of this project may be found at the TES web site.

Table of Contents:

1. Project Overview

1.1 Name of Project:

Tropospheric Emission Spectrometer

1.2 Project Introduction

See the Summary section above.

1.3 Project Mission Objectives

The primary objective of TES is to make global three-dimensional measurements of tropospheric ozone and of the physical and chemical factors that control its formation, destruction, and distribution. TES will generate data sets of the 3-D distribution of gases important to tropospheric chemistry, troposphere-biosphere interactions, and troposphere-stratosphere exchange, on global, regional, and local scales. These data sets will be used to improve models of the present and future state of Earth's lower atmosphere.

1.4 Disciplines

Earth Sciences
Atmospheric Sciences

1.5 Geographic Regions

The standard TES observation mode is to produce global survey standard products spanning 16 orbits on a 50% duty cycle, or approximately

every other day. The "off" days can be used for special observations such as intensive campaigns to observe volcanic eruptions, biomass burning, and pollution events.

The Aura satellite orbits at an altitude of 705 km in a sun-synchronous polar orbit with an exact 16 day repeat cycle. The orbital inclination is 98.1 degrees, providing latitudinal coverage from 82 N to 82 S.

A pictorial representation of the global survey ground target area is available which shows the typical coverage for a single 16 orbit global survey. Polar views are also available.

1.6 Detailed Project Description

The TES satellite instrument is an imaging infrared Fourier Transform Spectrometer (FTS). TES has both nadir and limb-viewing capability and covers the spectral range 650 - 2250 cm^{-1} at either 0.08 cm^{-1} or 0.02 cm^{-1} spectral resolution.

TES has 4 co-aligned focal plane detector arrays of 1x16 elements (pixels), each array optimized for a different spectral region. Each pixel Instantaneous Field-of-View (IFOV) is 0.075 mrad high by 0.75 mrad wide. At the limb, this corresponds to about 2.3 km altitude by 23 km parallel to the horizon. Limb measurements are made at the trailing limb, ~3100 km away. In the nadir, the footprint is 5 x 8 km. Each of the detector arrays is equipped with a filter wheel containing filters 200 - 300 cm^{-1} wide, both to reduce instrumental background noise and to permit interferogram sampling at relatively coarse intervals in order to reduce the data rate. A complete description of the TES experiment can be found in Reference 1. Table A gives a summary of TES instrument parameters.

The primary science operating mode for TES is the Global Survey. For Global Surveys, continuous sequences of a space view and a blackbody view calibration pair, nadir views and limb views are acquired. Each orbit is triggered by passage of the orbital southern apex, and an entire survey requires 16 orbits (about 26 hours). Each survey is preceded and followed by 2 orbits of pure space and blackbody views for calibration purposes. The Aura orbit has a 16-day repeat period so Global Surveys are made on a "1 day on, 1 day off" cycle, although the "off" time is significantly shorter than the "on" time. Triggering from the southern apex ensures that the same locations are observed repeatedly for the lifetime of the mission. Observations are made at the same latitudes during every orbit and on every 16^{th} day, identical locations are sampled. Global Surveys are the source of TES Standard Products.

Special Observations may be made during the 9 or 10 orbit gap between Global Surveys. These research observations fall into two general categories:

- targeted observations of specific locations such as volcanoes or biomass burning, or for localized validation, with +/- 45 degrees of nadir
- transect observations in the limb or nadir for observation of regional phenomena, such as the high ozone episodes that occur over the Eastern U.S. in the summer, and to support aircraft validation campaigns

Table A: TES Instrument Description

Parameters	Value
Spectrometer type	Connes-type four-port Fourier transform spectrometer
Overall spectral coverage	650 - 2250 cm^{-1} (4.5 - 15.4 µm)
Individual detector array spectral coverage	1A, 1900 - 2250 cm^{-1} 1B, 820 - 1150 cm^{-1} 2A, 1100 - 1950 cm^{-1} 2B, 650 - 900 cm^{-1}
Detector array configuration	1 x 16; all four arrays optically conjugated
Spectral accuracy	±0.00025 cm^{-1}
Spectral sampling distance	Interchangeably 0.0592 cm^{-1} downlooking and 0.0148 cm^{-1} at the limb
Spectral resolution	Interchangeably 0.08 cm^{-1} downlooking and 0.02 cm^{-1} at the limb
Spatial resolution	0.5 x 5 km nadir 2.3 x 23 km limb
Spatial coverage	5.3 x 8.5 km nadir 37 x 23 km limb
Field of regard	45° cone about nadir, plus trailing limb
Radiometric accuracy	<2 K, ~650 - 2250 cm^{-1}
Size	1.0 m x 1.3 m x 1.4 m
Mass	385 kg

Power	334 W average, 361 W peak
Data rate	4.5 Megabits per second, average

2. Data Availability

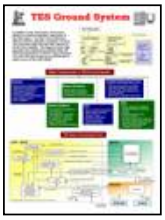
2.1 TES data processing and product levels

TES data are processed at the TES SIPS (Science Investigator-led Processing System) Facility in Pasadena, California, and the data are archived at the NASA Langley ASDC. TES data processing is implemented in four steps:

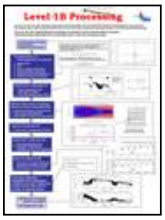
1. At Level 1A, the raw data from the spacecraft are decommutated and the interferograms reconstructed. File headers also contain important ancillary data such as time, date, spacecraft and target location, and instrument point angle.
2. At Level 1B, the interferograms are phase corrected and converted into spectra, radiometrically calibrated, corrected for off-axis instrument line-shape distortion, and resampled onto a common frequency grid. Certain data quality flags are added to the header.
3. At Level 2, vertical concentration profiles of the selected species are extracted from the spectra using a forward model based on a physical-chemical model of the expected atmospheric state, followed by a retrieval with appropriately constrained optimal estimation techniques. Complete error covariance matrices are generated to provide an objective estimate of the quality of the retrievals.
4. At Level 3, the profiles are resampled onto appropriate surfaces (e.g., pressure) to provide a series of maps, one for each set of species. Note: Level 3 products are not yet defined.

2.2 Processing details

This poster shows the TES Ground System and follows the high level data flow from the satellite to final products at the ASDC.



These two posters provide a more detailed description of the data processing paths, including input data and algorithms, for the TES Level 1B and Level 2 data.



Level 1B

Level 2

2.3 Product summary

There are two types of TES data products which correspond to the two instrument observation modes. Standard products are created for the Global Survey observations. Measurements taken in special observations mode are stored in a separate set of products. Level 1B and Level 2 products are produced for both types of observations.

Detailed information for both the standard and special observations products, including parameter names, descriptions, units, value ranges, size, and data type, as well as the file layout, is available in the TES Data Products Specifications document.

2.3.1 Level 1B Products

There are two Level 1B standard products, each associated with its own data set designation called an Earth Science Data Type (ESDT), one for nadir-viewed data and the other for limb-viewed data. Table B below provides summary information for these products. There are also two Level 1B Special Observation products, a low resolution product and a high resolution product, shown in Table C.

The primary parameters in the Level 1B products are spectra and noise-equivalent spectral radiance data. These files also include geolocation, engineering, production history, and data quality information.

At Level 1B, one granule is produced for each orbit, where a granule is the smallest orderable set of data. A Level 1B granule consists of four files, one for each of the four TES instrument focal planes. The Level 1B files are written using NCSA's HDF5 file format.

2.3.2 Level 2 Products

TES Level 2 files contain nadir- or limb-viewed measurements of a single molecular species (or temperature) for an entire 16-orbit Global Survey or for a Special Observation. The Level 2 Ancillary Data Product contains information such as geolocation and spacecraft position which are common to the individual Level 2 species and temperature files. Information for standard products is shown in Table B; Special Observation product information is given in Table C.

The primary parameters in the Level 2 products are the species volume mixing ratio or the temperature, along with precision and total error data. Level 2 data products are written using the HDF-EOS version 5 file format.

Table B. TES Standard Product Data Sets

Level	ESDT	Collection Summary	Principal Parameters	Format
Level 1B	TL1BN	TES Aura Level 1B Nadir	Spectra, Noise Equivalent Spectral Radiance (NESR)	HDF5
	TL1BL	TES Aura Level 1B Limb Observations	Spectra, Noise Equivalent Spectral Radiance (NESR)	HDF5
Level 2	TL2CH4N	TES Aura Level 2 CH4 Nadir Observations	CH4 Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2CON	TES Aura Level 2 CO Nadir Observations	CO Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2H2ON	TES Aura Level 2 H2O Nadir Observations	H2O Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2O3N	TES Aura Level 2 O3 Nadir Observations	O3 Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2CH4L	TES Aura Level 2 CH4 Limb Observations	CH4 Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2COL	TES Aura Level 2 CO Limb Observations	CO Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2H2OL	TES Aura Level 2 H2O Limb Observations	H2O Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2HNO3L	TES Aura Level 2 HNO3 Limb Observations	HNO3 Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2NO2L	TES Aura Level 2 NO2 Limb Observations	NO2 Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2O3L	TES Aura Level 2 O3 Limb Observations	O3 Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2ATMTN	TES Aura Level 2 Atmospheric Temperature Nadir Observations	Atmospheric Temperature, Temperature Precision and Vertical Resolution	HDF-EOS5
	TL2ATMTL	TES Aura Level 2 Atmospheric Temperature Limb Observations	Atmospheric Temperature, Temperature Precision and Vertical Resolution	HDF-EOS5
	TL2ANC	TES Aura Level 2 Ancillary Data	Cloud Cover, Spacecraft Position, Solar Azimuth Angle	HDF-EOS5

Level	ESDT	Collection Summary	Principal Parameters	Format
	TL2SUM	TES Aura Level 2 Summary Product	Summary profiles of Standard Product species	HDF-EOS5

Table C. TES Special Observation Product Data Sets

Level	ESDT	Collection Summary	Principal Parameters	Format
Level 1B	TL1BSOL	TES Aura Level 1B Special Observation Low Resolution	Spectra, Noise Equivalent Spectral Radiance (NESR)	HDF5
	TL1BSOH	TES Aura Level 1B Special Observation High Resolution	Spectra, Noise Equivalent Spectral Radiance (NESR)	HDF5
Level 2	TL2CH4NS	TES Aura Level 2 CH4 Nadir Special Observation	CH4 Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2CONS	TES Aura Level 2 CO Nadir Special Observation	CO Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2H2ONS	TES Aura Level 2 H2O Nadir Special Observation	H2O Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2O3NS	TES Aura Level 2 O3 Nadir Special Observation	O3 Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2CH4LS	TES Aura Level 2 CH4 Limb Special Observation	CH4 Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2COLS	TES Aura Level 2 CO Limb Special Observation	CO Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2H2OLS	TES Aura Level 2 H2O Limb Special Observation	H2O Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2HNO3S	TES Aura Level 2 HNO3 Limb Special Observation	HNO3 Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2NO2S	TES Aura Level 2 NO2 Limb Special Observation	NO2 Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2O3LS	TES Aura Level 2 O3 Limb Special Observation	O3 Volume Mixing Ratio, Precision, and Vertical Resolution	HDF-EOS5
	TL2ATNS	TES Aura Level 2 Atmospheric Temperature Nadir Special Observation	Atmospheric Temperature, Temperature Precision and Vertical Resolution	HDF-EOS5
	TL2TLS	TES Aura Level 2 Atmospheric Temperature Limb Special Observation	Atmospheric Temperature, Temperature Precision and Vertical Resolution	HDF-EOS5
	TL2ANCS	TES Aura Level 2 Ancillary Special Observation Data	Cloud Cover, Spacecraft Position, Solar Azimuth Angle	HDF-EOS5

2.4 Input/Output Media

Data will be made available to the user via File Transfer Protocol (FTP).

2.5 Proprietary Status

There is no proprietary status for the data sets available from the Langley ASDC.

3. Data Access

Publicly distributed TES data are accessible through the Reverb Search Tool and the ASDC Data Pool.

Reverb is the main search and order service for the Earth Observing System Data Information System (EOSDIS) Core System (ECS) and provides full access to distributed TES data. It allows users to search science data holdings, retrieve high-level descriptions of data sets and detailed descriptions of the data inventory, view browse images, and place orders for data products.

WISR search methods are available to aid the user in obtaining the desired data. A general search is made by specifying either a geophysical parameter, a data set name, or a sensor name. Three different search types provide increasingly detailed information about the science data available through the system. A directory search provides summary information about EOSDIS data sets. This type of search accesses the Global Change Master Directory (GCMD), a multidisciplinary database of information about Earth science data. An inventory search gives descriptions of specific observations or collections of observations of data (granules) that are available from a data center.

A Reverb browse function is also included which allows the user to preview data (possibly reduced in resolution) for those data products that provide a browse image, as an aid for selecting many of the products available from the data. Such data may be viewed in the Reverb interface or retrieved via FTP.

The Reverb order function allows the user to select the desired data processing options, and allows the user to specify contact, billing, and shipping addresses.

The Data Pool is an on-line, short-term data cache that provides a web interface and FTP access to portions of specific ASDC science data products.

The NASA Langley Atmospheric Science Data Center can provide additional assistance with ordering data products.

Data Center Location:

Atmospheric Science Data Center
NASA Langley Research Center

Contact Information:

User and Data Services Office
NASA Langley Research Center Atmospheric Science Data Center
Mail Stop 157D
Hampton, Virginia 23681-2199
U.S.A.
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov

Associated Costs:

Currently, there is no cost associated with this data.

4. Principal Investigator Information

Investigator(s) Name and Title:

Dr. Reinhard Beer
Jet Propulsion Laboratory
Mail Stop 183-601
California Institute of Technology
4800 Oak Grove Dr.
Pasadena, CA 91109-8001

Please direct inquiries to NASA Langley User Services: support-asdc@earthdata.nasa.gov

5. Submitting Investigator Information

Dr. Reinhard Beer

Jet Propulsion Laboratory
Mail Stop 183-601
California Institute of Technology
4800 Oak Grove Dr.
Pasadena, CA 91109-8001

Please direct inquiries to NASA Langley User Services: support-asdc@earthdata.nasa.gov

6. References

1. **Beer**, R., T. A. Glavich, and D. M. Rider, Tropospheric emission spectrometer for the Earth Observing System's Aura satellite, ***Applied Optics***, *40*, 2356-2367, **2001**. [Abstract]

A complete list of references can be found on the TES web site's Publications page.

7. Glossary and Acronyms:

EOSDIS Acronyms (PDF).

ASDC - Atmospheric Science Data Center
DAAC - Distributed Active Archive Center
ECS - EOSDIS Core System
EDOS - Earth Observing System Data and Operations System
EOS - Earth Observing System
EOSDIS - Earth Observing System Data Information System
ESDT - Earth Science Data Type
FTP - File Transfer Protocol
FTS - Fourier Transform Spectrometer
GCMD - Global Change Master Directory
HDF - Hierarchical Data Format
HDF-EOS - Hierarchical Data Format for the Earth Observing System
IFOV - Instantaneous Field of View
JPL - Jet Propulsion Laboratory
LaRC - Langley Research Center
NASA - National Aeronautics and Space Administration
NCSA - National Center for Supercomputing Applications
NESR - Noise Equivalent Spectral Radiance
SCF - Science Computing Facility
SIPS - Science Investigator-led Processing System
TES - Tropospheric Emission Spectrometer
WIST - Warehouse Inventory Search Tool

Also see the TES acronyms list.

8. Document Information

- **Document Creation Date:** January 2005
- **Document Review Date:** Jan 2005; Jan 2006
- **Document Revision Date:** Jan 2005; Jan 2006; Nov 2008
- **Document ID:**
- **Document Curator:** NASA Langley Atmospheric Science Data Center
  User and Data Services Office
  Telephone: (757) 864-8656
  FAX: (757) 864-8807
  E-mail: support-asdc@earthdata.nasa.gov