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Casey Seyb – November 12, 2019

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TROPOSPHERIC EMISSION SPECTROMETER (TES)

LEVEL 1A, 1B, 2 & 3 ALGORITHMS: SCIENTIFIC GOALS & REQUIREMENTS

Version 1.0
July 20, 1999

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TROPOSPHERIC EMISSION SPECTROMETER (TES)

LEVEL 1A, 1B, 2 & 3 ALGORITHMS: SCIENTIFIC GOALS & REQUIREMENTS

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INTRODUCTION

PURPOSE

The Level 1A, 1B, 2 & 3 Algorithms Scientific Goals & Requirements Document lists the goals and requirements for both the operational and SCF-maintained versions of the TES Data Analysis Algorithms. The intent is to provide a straightforward means for tracing the TES Science Team needs to the capabilities of the finished software.

SCOPE

The document is in twelve parts. Part I covers some over-arching system level requirements. Part II - V address the goals and requirements for the algorithms which are deliverable to the TES Operational Production Facility (TES OPF). Parts VI - IX cover those additional user interfaces required at the TES Science Computing Facility (TES SCF) at JPL. Part X covers the off line generation of the necessary input databases and the visualization tools needed at the SCF for both algorithm development and data quality assessment. Part XI discusses external user interfaces (i.e., what will be provided to the science community) and Part XII provides a list of acronyms.

Related topics that are not included here (but will be documented elsewhere) are:

hardware requirements
calibration data sorting strategy
detailed retrieval strategy (e.g., microwindow selection and retrieval sequencing)
detailed algorithm descriptions

All goals and requirements are either cross-referenced to the TES *Level 1B Algorithm Theoretical Basis Document* or the TES *Level 2 Algorithm Theoretical Basis Document* by section number or are identified as original within this document by the absence of such cross-reference.

APPLICABLE DOCUMENTS

Controlling Documents

1) Tropospheric Emission Spectrometer *Level 1B Algorithm Theoretical Basis Document*, JPL D-16479, Version 1.0, January 1999.

2) Tropospheric Emission Spectrometer *Level 2 Algorithm Theoretical Basis Document*, JPL D-16474, Version 1.0, January 29 1999.

Reference Documents

Tropospheric Emission Spectrometer *Scientific Objectives & Approach, Goals & Requirements*, JPL D-11294, Version 6.0, April 14 1999.

REVISION HISTORY

The original version of this document was dated July 20, 1999

Important note: Paper copies of this document may not be current and should not be relied upon for official purposes.
The current version is in the TES library at <http:/knowledge.jpl.nasa.gov/teslib/>

GENERAL DEFINITIONS:

Requirements are those aspects of the algorithms whose accomplishment is essential to produce valid data products. Requirements are suffixed with (R) and, where possible, referenced to the relevant section of the L1B or L2 ATBD.

Goals are those aspects whose accomplishment is highly desirable but of lower priority. Goals are suffixed by (G) and, where possible, referenced to the relevant section of the L1B or L2 ATBD.

In many cases, parameters are currently uncertain and labeled as TBD . However, wherever possible, the best current estimate is provided in parentheses.

PART I

SYSTEM-LEVEL GOALS & REQUIREMENTS

1.0 General Goals & Requirements

While not formally part of the algorithm goals and requirements, it is recognized that there are necessarily impacts on, for example, system performance parameters that must be considered in the design process:

1.1 Pursuant to a Program Level directive, all Standard Data Products for 1 Global Survey run shall be generated, using computational resources in an OPF provided by NASA, in a time not to exceed TBD (twice) the acquisition time (R).

some TBD latency to permit collection of necessary inputs is acceptable
this assumes that sufficient computing resources are available

1.2 The SCF-maintained algorithms shall mirror all the functionality and coding conventions of the OPF algorithms (R)

1.3 In addition, the SCF software shall permit the generation of Special Products and provide the tools for data and algorithm diagnostics (R).

1.4 The implementation of goals and requirements must follow the ordering specified herein (R).

PART II

GOALS & REQUIREMENTS FOR THE OPERATIONAL TES LEVEL 1A ALGORITHM

2.0 General Goals & Requirements

The Operational TES Level 1A algorithm shall:

2.1 Accept CCSDS data packets as primary input (R)

2.2 Reformat the data packets into 16-bit integer interferograms (R)

2.3 Archive the result as a Standard Product (R)

2.4 Using the State Data embedded into the data packets plus ancillary data such as a Digital Elevation Model of the Earth, determine the geolocation of the instrument boresight (center of the pixel array) at or near the time of Zero Path Difference and attach to the archived file (R)

at the surface for nadir
at the unrefracted tangent point for the limb

2.5 Generate flags to indicate (R)

Incomplete or corrupted data packets
State Data incomplete, corrupted or out of limits
Derived OPD velocity out of limits
Data numbers out of limits (TBD)

and attach to the archived file.

PART III

GOALS & REQUIREMENTS FOR THE OPERATIONAL TES LEVEL 1B ALGORITHM

3.0 General Goals & Requirements

The Operational TES Level 1B algorithm shall:

3.1 Accept TES Level 1A 16-bit interferograms as primary input (R, L1B §3.2).

3.2 Convert the input integer interferograms to IEEE 32-bit floating-point format (R, L1B §3.2).

3.3 Apply the appropriate gain factor and, if necessary, correct for non-linearity (R, L1B §4.2).

3.4 Perform a logical left shift on the interferogram to rotate the largest peak down to the origin (index zero) (R, L1B §4.3).

3.5 Truncate the interferogram to a pre-determined (TBD) array size (R, L1B §4.3).

> This array size must have low prime-factor values for efficiency and also account for the possible offset of the point closest to ZPD from the center of the interferogram array.

3.6 Perform a real-to-complex discrete Fourier transform on the result of §3.5 using a TBD (possibly the FFTW) prime factor algorithm (R, L1B §4.4).

The following requirements (§3.7 to §3.10) apply to calibration (cold space and 340K blackbody) spectra only:

3.7 On a TBD interval, use 340K black body spectra resulting from §3.6 to generate a 'spike-deweighting' mask for subsequent application to all spectra (R, L1B §4.5).

3.8 Rotate the phase of all black body and cold space spectra to a common phase (R, L1B §5.2).

3.9 As an option, perform Optimal Phase Correction or a 'classic' (e.g., Forman, Steele & Vanasse) phase corrrection (R, L1B Appendix B).

3.10 Interpolate the calibration spectra to match high resolution limb data. If necessary, apply corrections from limb resolution calibration data taken as special calibration measurements at TBD intervals (R, L1B §5.5.2).

The following requirements (§3.11 to §3.25) apply to target (limb and nadir) spectra only:

3.13 Apply the spike-deweighting mask as found by §3.7 . (R)

3.14 Rotate the phase of the target spectra to the same common phase as in §3.8 (R, L1B §5.5.1).

3.15 Compute or read in pre-computed tabulated frequency scales and corresponding Planck functions. (R, L1B §5.4)

Note that frequency scales are pixel dependent due to the different off-axis angles.

3.16 Using 340K and cold space calibration spectra, time-interpolated to the time of the target spectrum, and the Planck function, perform a complex radiometric calibration on the target spectrum. (R, L1B §5.5)

3.17 Estimate the NESR (Noise Equivalent Spectral Radiance) for the calibrated target spectrum either from the out-of-band RMS uncalibrated target power spectrum or by applying the NESR generated using statistics with several imaginary terms of spectra after complex calibration for target scenes of the same location. Note that the imaginary terms of spectra after complex calibration are an intermediate product. (R, L1B §5.6)

3.18 Perform the Instrument Line Shape (ILS) correction by splitting the interferogram into frequency sub-bands, applying the self-apodization correction term appropriate to each frequency sub-band and recombining the sub-bands. (R, L1B §6.3)

3.19 Apply Doppler correction to the limb frequency scales.(R, L1B §7.1)

3.20 Apply the frequency scale corrections from §3.20 and resample the spectrum to a common, on-axis Level 2 frequency (TBD) grid (0.06 cm^{-1} for nadir, 0.015 cm^{-1} for limb). (R, L1B §7.2).

3.21 Archive the result as a Standard Product (R)

3.22 Using the TBD algorithm, determine the cloud contamination flag (R, L1B §8.2).

3.23 Compute the filter band mean and peak radiances and brightness temperatures and attach to the output file (R).

3.24 Attach the L1A data quality flags to each output single-filter spectrum file (R).

3.25 Generate quality flags to be attached to each output single-filter spectrum file (R, L1B§8.1) when:

in nadir data, pixel-to-pixel radiance differences exceed a TBD (5%) threshold
cloud interference is suspected
the calculated NESR exceeds the expected NESR by more than a factor of TBD (2)
the imaginary part of the spectrum has a mean value that differs from zero by more than TBD (5%)
the mean value of the out-of-band radiances differ from zero by more than TBD (2%)
the peak and/or mean spectral radiance differs from expectations by more than a factor of TBD (2)

PART IV

GOALS & REQUIREMENTS FOR THE OPERATIONAL TES LEVEL 2 ALGORITHM

DEFINITIONS:

Forward Model is that part of the L2 algorithm that creates both a *simulacrum* of the received radiance based on specified input parameters and its partial derivatives with respect to the retrieved parameters.

Retrieval is that part of the L2 algorithm that compares the forward model to the observation and, *via* specified rules, changes the forward model input parameters and iterates until, *via* other specified rules, the forward model matches the observation to within some specified limit.

4.0 General Goals & Requirements

The Operational TES Level 2 algorithm shall:

4.1 Accept TES Level 1B limb and nadir calibrated spectral radiances as primary input (R, L2§3.1).

4.2 Retrieve an atmospheric temperature profile with respect to dry air at specified pressure levels from both limb and nadir observations from as near to the surface as possible down to a pressure of TBD (4.6) hPa (R, L2§2.4).

4.3 Retrieve the surface skin temperature from TES nadir observations (R, L2§3.5.3.1).

4.4 Retrieve the surface emissivity at the frequency grid spacing specified by the surface emissivity database from TES nadir observations over land (R, L2§3.5.3.1).

4.5 Retrieve Volume Mixing Ratio (VMR) vertical profiles with respect to dry air at specified pressure levels from TES limb observations of

Ozone (O_3)
Water Vapor (H_2O)
Carbon Monoxide (CO)
Methane (CH_4)
Nitric Oxide (NO)
Nitrogen Dioxide (NO_2)
Nitric Acid (HNO_3)

from as near to the surface as possible down to a pressure of TBD (4.6) hPa (R, L2§2.4).

4.6 Retrieve Volume Mixing Ratio (VMR) vertical profiles with respect to dry air at specified pressure levels from TES nadir observations of

Ozone (O_3)
Water Vapor (H_2O)
Carbon Monoxide (CO)
Methane (CH_4)

from as near to the surface as possible down to a pressure of TBD (4.6) hPa (R, L2§2.4).

4.7 Permit expandable archiving of the results at the Langley DAAC together with (R, L2§2.4)

a header containing time, date, latitude, longitude, observation mode and solar zenith angle at acquisition
the total column density of retrieved species
a full forward model spectrum over the filter bands employed[1]
a full error covariance matrix
a 1 estimate of the random error (square root of the diagonal of the error covariance matrix)
an estimate of the systematic errors
an estimate of the fraction of explained variance
for profiles, an estimate of the correlation length
the data quality flags from L1A and L1B
the final TBD (^{2}) convergence criterion
the number of iterations required to achieve convergence
the mean absolute deviation between the final forward model and the data
the peak absolute deviation between the final forward model and the data

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[1] The observed radiance with which this is to be compared was previously archived at Level 1B

5.0 Forward Model Goals & Requirements

The Forward Model segment of the deliverable TES Level 2 algorithm shall:

5.1 Permit the use of multiple microwindows (R)

5.2 Employ the full state vectors specified below for defining parameters that describe the currently-estimated state of the atmosphere and surface for calculating limb and nadir radiances (R, L2§3.2.2).

5.2.1 The full state vector for calculating nadir radiances comprises:

surface pressure
temperature on a specified pressure grid
constituent mixing ratios on a specified pressure grid
aerosol extinction coefficients on specified pressure and frequency grids
surface skin temperature
surface emissivity on a specified frequency grid
surface albedo/reflectivity on a specified frequency grid
surface bi-directional reflectivity distribution function on a specified frequency grid
instrumental line shape (ILS)
altitude of a reference pressure
nadir view angle
Sun angle at the nadir location

5.2.2 The full state vector for calculating limb radiances comprises:

temperature on a specified pressure grid
constituent mixing ratios on a specified pressure grid
aerosol extinction coefficients on specified pressure and frequency grids
instrumental line shape (ILS)
altitude of a reference pressure
spacecraft position
look angle of the boresight from the spacecraft
instrumental field-of-view function
Sun angle at the tangent point location

5.3 Incorporate as constants (R, L2§3.2.2)

constituent absorption coefficients on a specified frequency, pressure and temperature grid
continuum absorption coefficients for specified species
cloud/aerosol extinction
a digital elevation model
a surface characterization map or global land cover database

5.4 Incorporate a flexible list of additional species including, but not limited to (R & G, L2§2.5):

Hydrogen Peroxide	H_2O_2	(G)
Monodeuterated Water Vapor	HDO	(R)
Ethane	C_2H_6	(G)
Acetylene	C_2H_2	(G)
Formic Acid	HCOOH	(R)
Methyl Alcohol	CH_3OH	(R)
Peroxyacetyl Nitrate	$CH_3C(O)NO_2$	(G)
Acetone	$CH_3C(O)CH_3$	(R)
Ethylene	C_2H_4	(G)
Peroxynitric Acid	HO_2NO_2	(R)
Ammonia	NH_3	(R)
Hydrogen Cyanide	HCN	(G)
Nitrous Oxide	N_2O	(R)
Dinitrogen Pentoxide	N_2O_5	(R)
Chlorine Nitrate	$C\ ONO_2$	(R)
Carbon Tetrachloride	$CC\ _4$	(G)
CFC-11	$CC\ _3F$	(R)
CFC-12	$CC\ _2F_2$	(R)
HCFC-21	$CHC\ _2F$	(G)
HCFC-22	$CHC\ F_2$	(G)
Sulphur Dioxide	SO_2	(R)
Carbonyl Sulphide	OCS	(R)
Hydrogen Sulphide	H_2S	(G)
Sulphur Hexafluoride	SF_6	(R)

5.5 Employ a configurable superset of the UARS pressure grid for the full state vector (R, L2§3.2.3).

5.6 Employ a TBD (0.0002) cm^{-1} frequency grid for calculating radiances (R, L2§3.2.4)

5.7 Calculate the refracted ray path through the atmosphere (R, L2§3.3.1.1)

5.8 Employ a Numerical Weather Prediction model to determine the thickness of the surface layer (R, L2§3.3.1.2)

5.9 Calculate the optical depth along the line of sight at each specified layer and frequency (R, L2§3.3.1.3)

5.10 Calculate the atmospheric emitted radiances using recursion relations (R, L2§3.3.1.4)

5.11 Account for breakdown of Local Thermodynamic Equilibrium (non-LTE) in forward model layers below TBD (10) hPa (G, L2§3.3.1.5)

5.12 Incorporate surface backscatter for solar radiation at frequencies above TBD (2000) cm^{-1} (R, L2§3.3.1.6)

5.13 Incorporate aerosol backscatter for solar radiation at frequencies above TBD (2000) cm^{-1} (G)

5.14 Incorporate surface emission and reflection effects (R, L2§3.3.1.7)

5.15 For limb radiances, calculate TBD (40, max 100) rays simultaneously (R, L2§3.3.1.8)

5.16 Account for line-of-sight constituent inhomogeneity in the limb mode (G, L2§3.3.1.9)

5.17 Apply the best estimate ILS to the monochromatic radiances through a process of convolution using the residual ILS models from L1B applied to frequency sub-bands (R, L2§3.3.5)

5.18 For limb data, apply the best estimate Instrumental Field-of-View to the resultant radiances from 5.15 through a process of convolution (R, L2§3.3.6)

5.19 Generate the partial derivatives of the radiance with respect to each of the retrieved parameters (the Jacobians) and other parameters (R, L2§3.4 & TBD)

Jacobians are analytic and, where necessary, calculated by finite differences

5.20 Provide internal accuracy, with respect to the reference forward model of better than TBD (0.1) % Mean Absolute Deviation and a Peak Deviation not to exceed TB (0.5) % (R, L2§TBD)

exclusive of instrument noise and input parameter systematic errors

6.0 Retrieval Goals & Requirements

The Retrieval segment of the deliverable TES Level 2 algorithm shall:

6.1 Employ onion-peeling retrieval for initial guess refinement at the limb (R, L2§3.5.4)

6.2 Generate a retrieval vector that contains as a minimum (R, L2§3.5.2)

> surface skin temperature (nadir only)
> surface spectral emissivity for a specified spectral range (nadir only)
> atmospheric temperature profile on contiguous levels of the retrieval pressure grid
> ln(constituent mixing ratio) profiles on contiguous levels of the retrieval pressure grid
> aerosol extinction coefficients on contiguous levels of the retrieval pressure grid
> the angle of the TES boresight

6.3 Employ a TBD (UARS) retrieval pressure grid (R, L2§3.3.3)

6.4 Interpolate the retrieved parameter back onto the forward model grid either using direct parameter values for temperature and their natural logarithms for VMRs to initialize the next iteration (R, L2§3.5.2)

6.5 Employ *a priori* data to constrain possible solutions (R, L2§3.5.3)

6.6 Construct a cost function using the measurement, the forward model spectrum and the *a priori* (R, L2§3.5.4.3)

6.7 Minimize the cost function using a TBD (Levenberg-Marquardt) iteration method (R, L2§3.5.4.4)

6.8 Determine convergence of the solution using a TBD (^{2}) test (R, L2§3.5.4.4)

6.9 Generate full error covariance and averaging kernel matrices on output (R, L2§3.5.9)

6.10 Provide internal accuracy, with respect to test profiles, of better than TBD (0.1) K Mean Absolute Deviation and a Peak Deviation not to exceed TBD (0.5) K for temperatures (R, L2§TBD)

6.11 Provide internal accuracy, with respect to test profiles, of better than TBD (0.2) % Mean Absolute Deviation and a Peak Deviation not to exceed TBD (1.0) % for VMRs (R, L2§TBD)

> exclusive of instrument noise and input parameter systematic errors
> including forward model errors

PART V

GOALS & REQUIREMENTS FOR THE OPERATIONAL TES LEVEL 3 ALGORITHM

7.0 General Goals & Requirements

The Operational TES Level 3 algorithm shall:

7.1 Accept TES Level 2 Temperatures and VMR profiles as primary input (R).

7.2 If necessary, interpolate the profiles on to a TBD (UARS) pressure grid (R)

7.3 On each pressure surface, interpolate TBD (8) consecutive days-worth of Global Survey data onto global maps having a TBD (5° x 5°) latitude-longitude grid (R)

PART VI

ADDITIONAL GOALS & REQUIREMENTS FOR THE TES SCF-MAINTAINED LEVEL 1A ALGORITHM

8.0 User Interface to the Goals & Requirements of Part II

The SCF-Maintained Level 1A algorithm shall also:

8.1 Provide a means of incorporating and validating all new or replacement algorithms (R)

8.2 Provide a means of modifying and validating all approximations used in the operational algorithm (R)

8.3 Provide a Graphical User Interface (GUI) (R)

PART VII

ADDITIONAL GOALS & REQUIREMENTS FOR THE TES SCF-MAINTAINED LEVEL 1B ALGORITHM

9.0 User Interface to the Goals & Requirements of Part III

The SCF-Maintained Level 1B algorithm shall also:

9.1 Provide a means of incorporating and validating all new or replacement algorithms (R)

9.2 Provide a means of modifying and validating all approximations used in the operational algorithm (R)

9.3 Provide a Graphical User Interface (GUI) (R)

9.4 Permit the analysis of non-TES data sets (e.g., AES. IMG, MIPAS, etc.) (R)

PART VIII

ADDITIONAL GOALS & REQUIREMENTS FOR THE TES SCF-MAINTAINED LEVEL 2 ALGORITHM

10.0 User Interface to the Goals & Requirements of Part IV

The SCF-Maintained Level 2 algorithm shall also:

10.1 Provide a means for generating the reference forward models used for evaluating the approximations in the operational forward models. (R) These reference forward models must include:

a line-by-line algorithm for optical depths without line rejection
an exact calculation of the Planck function
a superset of the operational forward model pressure levels such that further subdivision of pressure levels generates radiance changes that are less than TBD (.01%)
exact exponential calculations

10.2 Provide a means of incorporating and validating all new or replacement algorithms (R)

10.3 Provide a means of modifying and validating all approximations used in the operational algorithm (R)

10.4 Provide a Graphical User Interface (GUI) (R)

10.5 Permit the analysis of non-TES data sets (e.g., AES. IMG, MIPAS, etc.) (R)

10.6 Provide finite difference derivative capability for all parameters (e.g., to validate analytic derivatives)

10.7 Permit the retrieval of VMR s in addition to ln(VMR)

PART IX

ADDITIONAL GOALS & REQUIREMENTS FOR THE TES SCF-MAINTAINED LEVEL 3 ALGORITHM

11.0 User Interface to the Goals & Requirements of Part V

The SCF-Maintained Level 3 algorithm shall also:

11.1 Provide a means of incorporating and validating all new or replacement algorithms (R)

11.2 Provide a means of modifying and validating all approximations used in the operational algorithm (R)

11.3 Provide a Graphical User Interface (GUI) (R)

PART X

GOALS & REQUIREMENTS FOR SUPPORT FUNCTIONS

12.0 Level 1A Support Function Goals & Requirements

The Level 1A segment of the SCF-maintained algorithms shall:

12.1 Provide a means for maintaining and validating all databases used by both the operational and research algorithms, *viz:* (R)

13.0 Level 1B Support Function Goals & Requirements

The Level 1B segment of the SCF-maintained algorithms shall:

13.1 Provide a means for creating, maintaining and validating all databases and intermediate products used by both the operational and research algorithms, *viz:* (R)

- Spike frequency location tables
- Averaged complex calibration spectra
- Computed gain spectra for instrument diagnostics
- NESR estimates using ensembles of real and imaginary calibrated target spectra
- L1B ILS correcting functions and residuals (for L2 modeling) using
    - Angular position of each pixel
    - Pixel responses
- Cross-correlate zonal averages of Global Survey spectra with pre-computed model spectra to determine the linear coefficients for frequency scale corrections. (R, L1B §7.1.2)
- Radiance threshold for cloud identification

14.0 Level 2 Support Function Goals & Requirements

The Level 2 segment of the SCF-maintained algorithms shall:

14.1 Provide a means for creating, maintaining and validating all databases used by both the operational and research algorithms, *viz:* (R)

Microwindow selection for maximum information content and minimum error
Absorption coefficient tables
Atmospheric models of temperature and constituent profiles
Land surface models
Digital elevation models
Pixel response models for FOV convolution

14.2 Permit the interactive modification of copies of the foregoing in both tabular and graphical format. That is, a change in the graphical display shall be reflected in the tabulation and *vice versa.* (G)

15.0 Level 3 Support Function Goals & Requirements

The Level 3 segment of the SCF-maintained algorithms shall:

16.0 Visualization Goals & Requirements

The Visualization segment of the SCF-maintained Level 1B & Level 2 algorithms shall provide on-screen and publication-quality hardcopy graphics of:

16.1 Raw Integer, Raw Floating-Point and Phase-Corrected Interferograms as a function of (R)

amplitude in instrument values [linear Y-axis] *or*
relative amplitude [linear Y-axis] *and*
index number [linear X-axis, user selected range] *or*
Optical Path Difference in cm [linear X-axis, user selected range]

16.2 Histograms of Raw Integer Interferograms as a function of (R)

summation in Data Number (DN) bin [linear Y-axis] *and*
DN [linear X-axis, user selected range]

16.3 Interferogram Phase as a function of (R)

phase in radians [linear Y-axis] *or*
phase in degrees [linear Y-axis] *and*
index number [linear X-axis, user selected range] *or*
Optical Path Difference in cm [linear X-axis, user selected range]

16.4 Uncalibrated spectra as a function of (R)

amplitude in instrument units [linear Y-axis] *or*
relative amplitude [linear Y-axis] *and*
frequency in cm^{-1} [linear X-axis, user selected range] *or*
wavelength in m [linear X-axis, user selected range]

16.5 Model and/or observed radiance spectra and/or their differences as a function of (R)

radiance in watts/cm^2/sr/cm^{-1} [linear Y-axis] *or*
brightness temperature in kelvins [linear Y-axis] *and*
frequency in cm^{-1} [linear X-axis, user selected range] *or*
wavelength in m [linear X-axis, user selected range]

16.6 Cross-correlation among any pair-wise combination of uncalibrated, radiance calibrated and model spectra as a function of (R)

> correlation amplitude [linear Y-axis] *and*
> lead/lag in index number [linear X-axis, user selected range] *or*
> lead/lag in cm^{-1} [linear X-axis, user selected range]

16.7 Model and retrieved constituent profiles with 1 error bars as a function of (R)

> pressure in hPa [$\log_{10}$ Y-axis] *or*
> potential temperature in kelvins [linear Y-axis] *or*
> approximate altitude in km [linear Y-axis] *and*
> volume mixing ratio [linear X-axis] *or*
> volume mixing ratio [$\log_{10}$ X-axis] *or*
> concentration in molecules/m^3 [linear X-axis] *or*
> concentration in molecules/m^3 [$\log_{10}$ X-axis]

16.8 Model and retrieved temperature profiles with 1 error bars as a function of (R)

> pressure in hPa [$\log_{10}$ Y-axis] *or*
> potential temperature in kelvins [linear Y-axis] *or*
> approximate altitude in km [linear Y-axis] *and*
> temperature in kelvins [linear X-axis]

16.9 Jacobians for temperature and constituents as a function of (R)

> (radiance in watts/cm^2/sr/cm^{-1})/ (parameter) [linear Y-axis] *and*
> frequency in cm^{-1} [linear X-axis, user selected range]

16.10 Weighting Functions for temperature and constituents at user-specified frequencies as a function of (R)

> pressure in hPa [$\log_{10}$ Y-axis] *or*
> potential temperature in kelvins [linear Y-axis] *or*
> approximate altitude in km [linear Y-axis] *and*
> (transmittance)/ (Y parameter) [linear X-axis]

16.11 Contribution Functions with an optional overlay of the Planck Function for temperature and constituents at user-specified frequencies as a function of (R)

pressure in hPa [$\log_{10}$ Y-axis] *or*
potential temperature in kelvins [linear Y-axis] *or*
approximate altitude in km [linear Y-axis] *and*
radiance in watts/cm^2/sr/cm^{-1} [linear X-axis] *or*
radiance in watts/cm^2/sr/cm^{-1} [$\log_{10}$ X-axis] *or*
brightness temperature in kelvins [linear X-axis]

16.12 Averaging Kernels for temperature and constituents as a function of (R)

pressure in hPa [$\log_{10}$ Y-axis] *or*
potential temperature in kelvins [linear Y-axis] *or*
approximate altitude in km [linear Y-axis] *and*
amplitude [linear X-axis]

16.13 Eigenvectors and eigenvalues of $\mathbf{K}^T\mathbf{S}_e^{-1}\mathbf{K}$ as a function of (R)

pressure in hPa [$\log_{10}$ Y-axis] *and*
amplitude [linear X-axis]

16.14 Eigenvectors and eigenvalues of Averaging Kernels for temperature and constituents as a function of (R)

pressure in hPa [$\log_{10}$ Y-axis] *and*
amplitude [linear X-axis]

16.15 Empirical Orthogonal Functions of the *a priori* Covariance $\mathbf{S}_a$ as a function of (R)

pressure in hPa [$\log_{10}$ Y-axis] *and*
amplitude [linear X-axis]

PART XI

GOALS & REQUIREMENTS FOR THE EXTERNAL USER INTERFACE

The External User Interface for TES Standard Data Products shall:

17.1 Permit access to all Level 1B, Level 2 and Level 3 Standard Data Products by (R)

specific date and/or time
range of dates and/or times
latitude and longitude points
latitude and longitude ranges
any appropriate combination of the above

17.2 For every atmospheric product at every requested (or closest available) retrieval level, provide (R, L2§2.4)

either temperature *or* volume mixing ratio with respect to dry air
1 sigma standard deviation [square root of the error matrix diagonal]
estimate of the systematic error
fraction of explained variance
correlation length

17.3 For nadir views of the surface, also provide (R, L2§2.4)

surface skin temperature
retrieved land surface emissivity at fixed, pre-selected, frequencies
1 sigma standard deviation [square root of the error matrix diagonal]
estimate of the systematic error
fraction of explained variance

17.4 Provide the full output error covariance matrix $\mathbf{S}_e$ (R, L2§2.4)

17.5 Provide a visual guide to available products (browse tool) from each Global Survey Run consisting of (R)

interpolated global maps of total column densities
interpolated global maps of temperature or concentration at any requested (or closest available) retrieval pressure level
provide a point-and-click interface between the maps and the underlying profiles

PART XII

LIST OF ACRONYMS

AES	Airborne Emission Spectrometer (JPL)
ATBD	Algorithm Theoretical Basis Document
CCSDS	Consultative Committee for Space Data Systems
DAAC	Distributed Active Archive Center (at NASA Langley RC)
FOV	Field of View
ILS	Instrumental Line Shape (Spectral Impulse Response)
IMG	Interferometric Monitor of Greenhouse Gases (Japan)
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding (ESA)
NESR	Noise Equivalent Source Radiance
OPD	Optical Path Difference
OPF	Operational Computing Facility (location TBD)
SCF	Science Computing Facility (at JPL)
TBD	To Be Determined
TBS	To Be Specified
TES	Tropospheric Emission Spectrometer
VMR	Volume Mixing Ratio (= Partial Pressure)
ZPD	Zero Path Difference