Radiometric and Frequency Calibration of EOS-Aura TES Infrared Spectra

A33A-0121

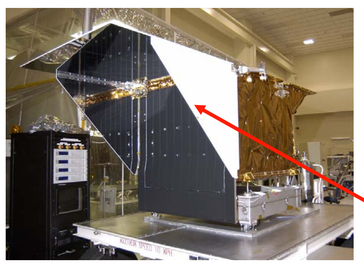
Helen M. Worden, Reinhard Beer, Kevin W. Bowman, Brendan Fisher, Mingzhao Luo, Gregory Osterman, David Rider, Edwin Sarkissian — Jet Propulsion Laboratory, Cal Tech

Denis Tremblay — Raytheon Systems, ITSS

ABSTRACT

TES is an infrared Fourier transform spectrometer on board the EOS-Aura spacecraft. The first on-orbit interferograms were acquired August 20, 2004. We present the methods for producing calibrated radiance spectra and show initial results for atmospheric nadir and limb spectra. We also show comparisons of TES nadir spectra to Aqua-AIRS spectra, where the AIRS data are taken on the same orbit path about 15 minutes before TES data are taken.

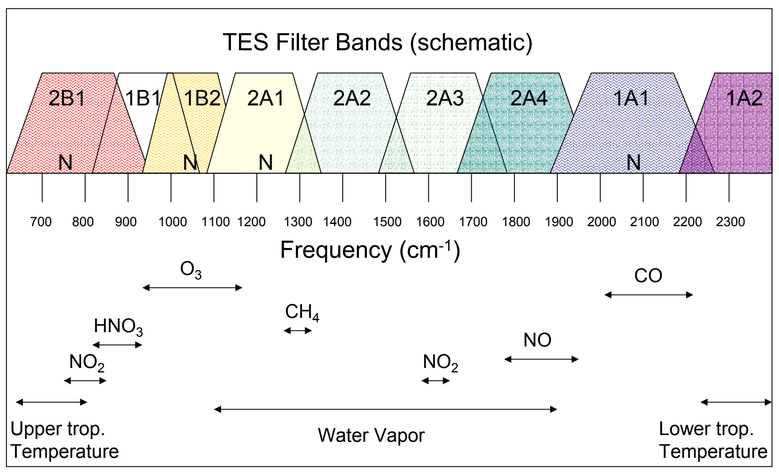
TES on EOS-Aura



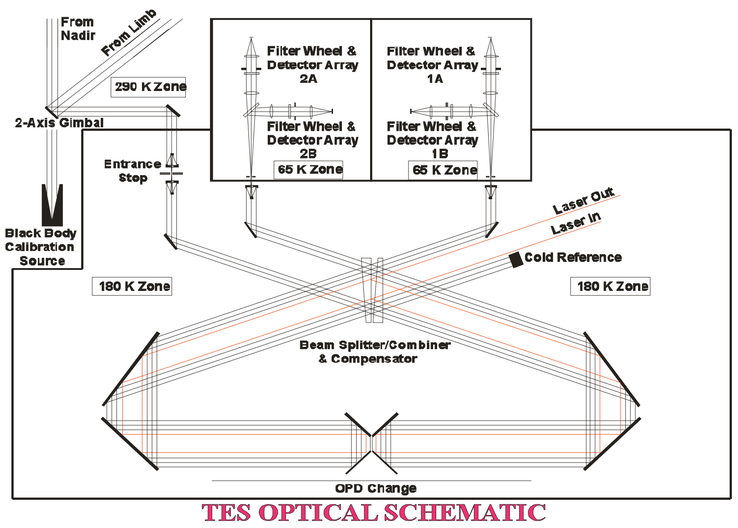
- Fourier transform spectrometer
- Wavelength response: 5 to 15.4 micron
- One scan every 4 or 16 sec. (0.1 cm^{-1} or 0.025 cm^{-1} res.)
- Four optically-conjugated 1x16 pixel detector arrays
- Spatial resolution of 5 x 8 km at nadir & 2.3 km at limb
- Passively cooled
- 2-axis gimbaled pointing mirror (nadir & limb viewing)

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.

TES Spectral Coverage for Ozone and Its Precursors



RADIOMETRIC CALIBRATION



TES OPTICAL SCHEMATIC

Calibration Issues & Systematic Error Sources

- Time Dependence of instrument response and offset
  - Ice Buildup
  - shear
  - Orbital variations
- Scan to Scan Phase Alignment
  - Needs to be more robust
- Possible angle dependence

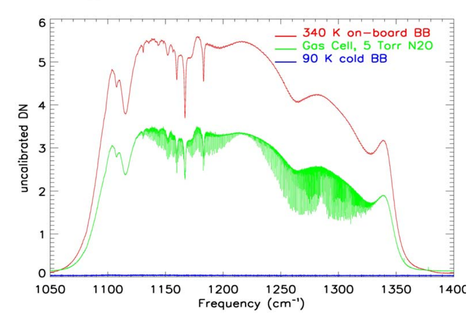
Complex Calibration:

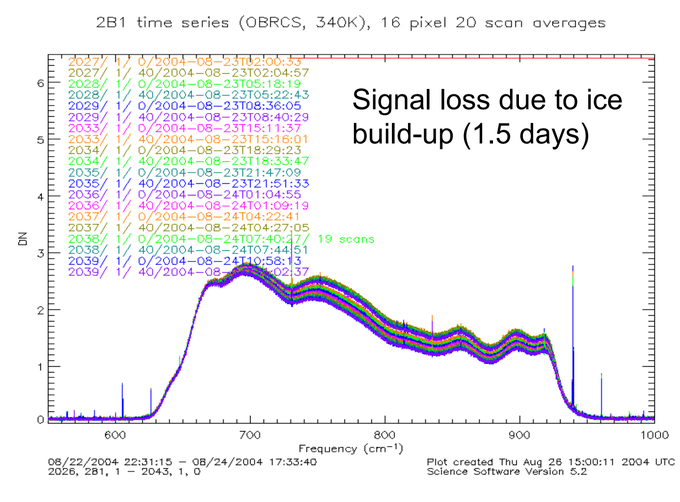
$$C_{tgt} = r(L_{tgt} + L_{fo} - L_{cr} + L_{ifmtr} e^{i\varphi_\delta}) e^{i\varphi} e^{i2\pi m\nu/\nu_l}$$

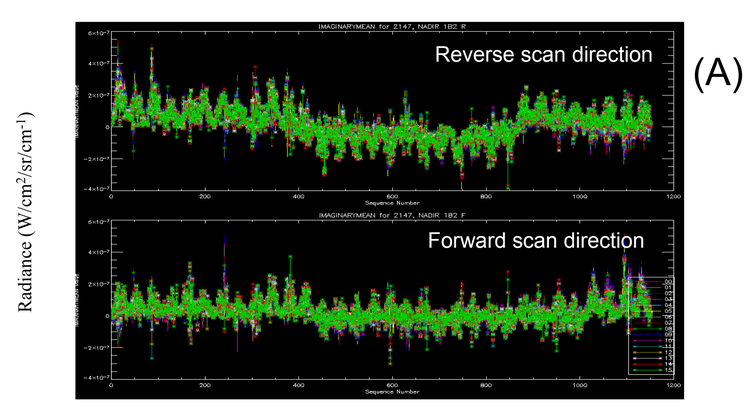
$C = C(\nu, t)$ = complex spectrum
L_{tgt} = target radiance
L_{fo} = foreoptics radiance
L_{cr} = cold reference radiance
L_{ifmtr} = interferometer radiance
r = instrument response (radiometric slope)
ϕ_δ = phase of interferometer emission
ϕ = net optical and electronics phase
ϕ_δ = phase of interferometer emission
$2\pi m\nu/\nu_l$ = sampling phase (ν_l = laser freq.)

$$L_{tgt} = \frac{C_{tgt} - C_{CS}}{C_{BB} - C_{CS}} \varepsilon_{BB} B(T_{BB})$$

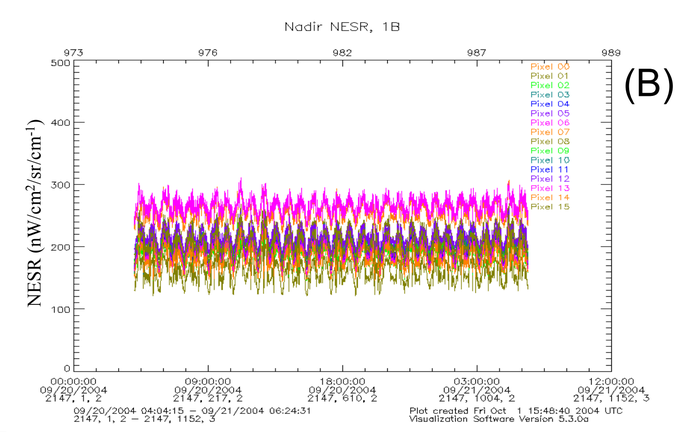
C_{CS} = cold space complex spectrum
C_{BB} = on-board blackbody complex spectrum
ε_{BB} = blackbody emissivity
$B(T_{BB})$ = Planck function for blackbody







(A)

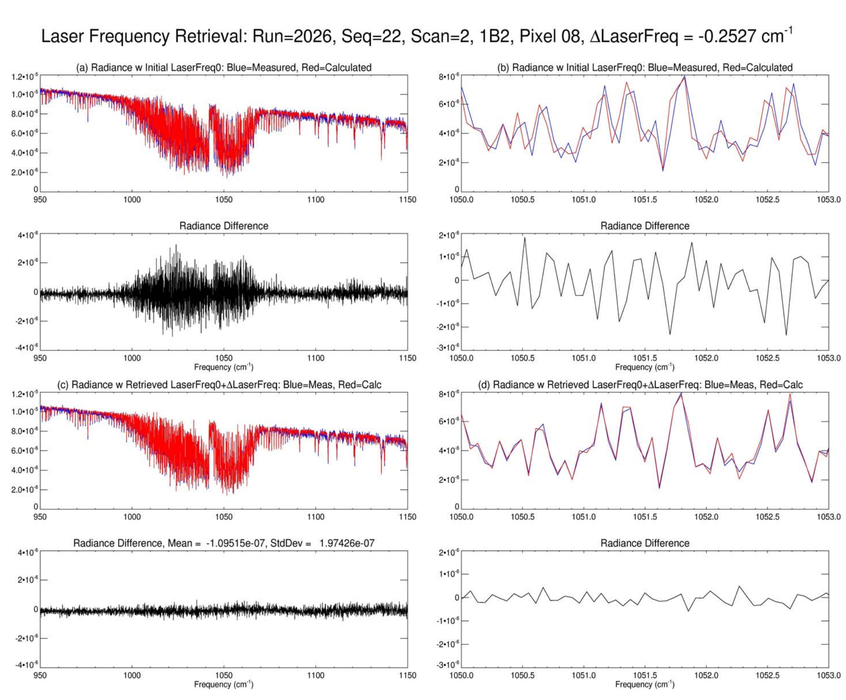


(B)

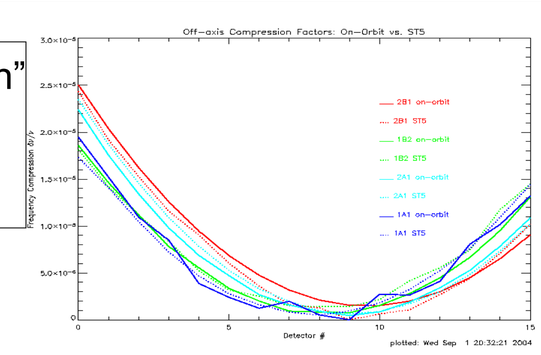
L1B Calibration Error Estimates

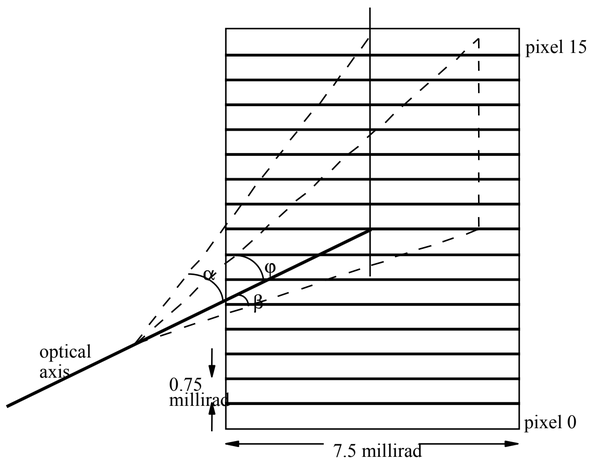
A) The imaginary mean is a measure of the residual radiance remaining in the imaginary term after complex calibration. Ideally, this should be unbiased with RMS close to the noise level. Variations from this indicate systematic calibration errors.
B) Spectral averages of estimated NESR (Noise Equivalent Spectral Radiance)

FREQUENCY CALIBRATION

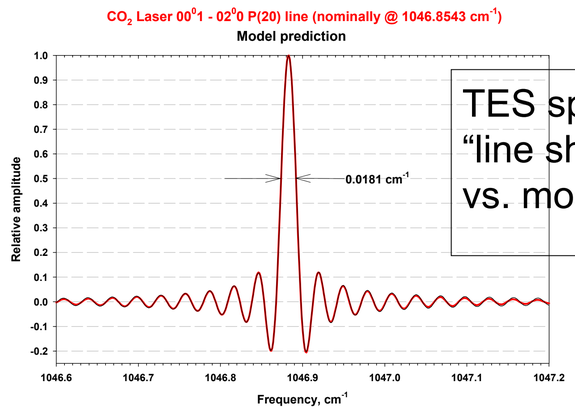


Frequency "compression" ($\delta\nu/\nu$) due to off axis angles.





TES detector array with respect to the optical axis, showing off-axis geometry



TES spectral response "line shape" - measured vs. modeled.

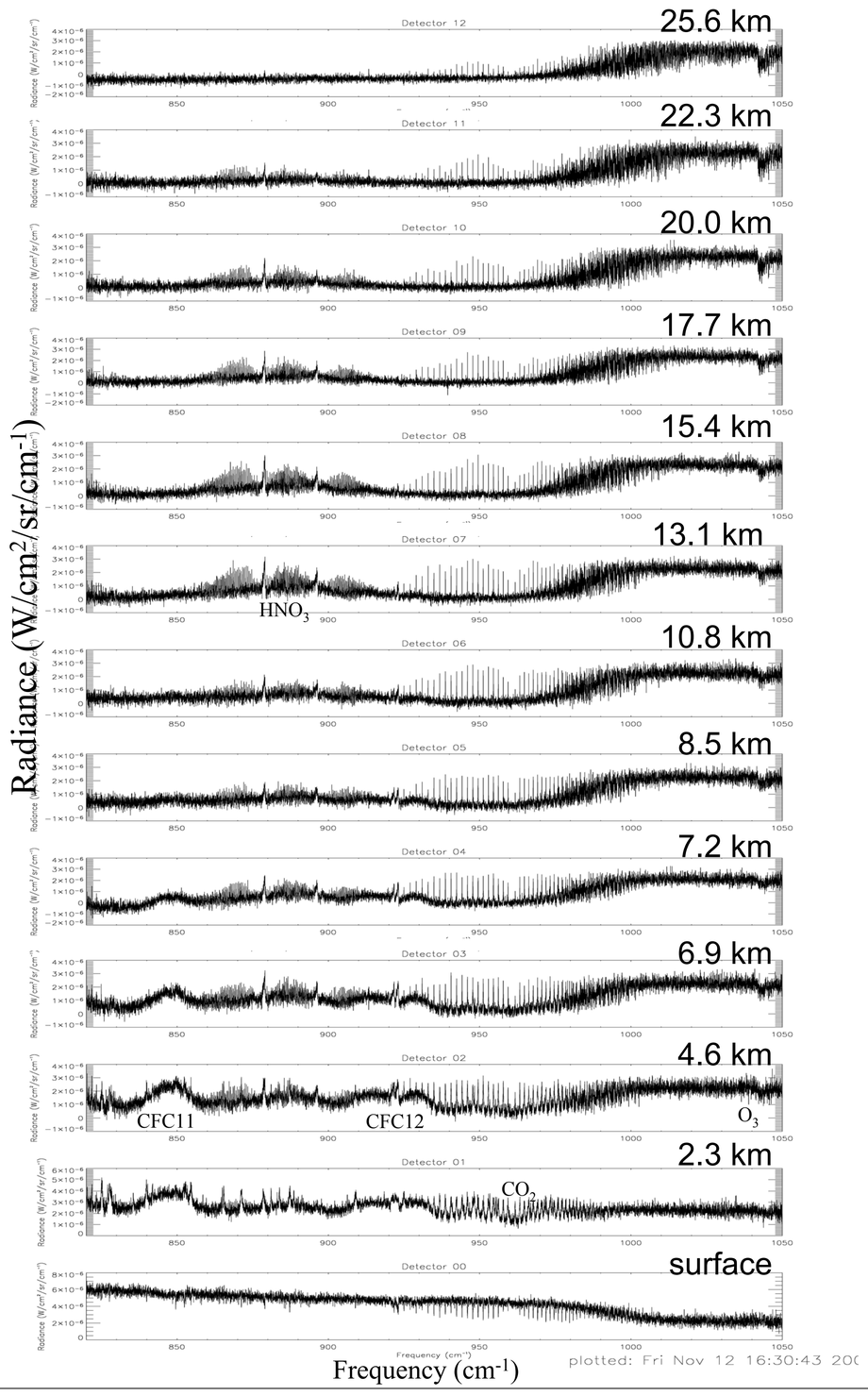
http://tes.jpl.nasa.gov

Radiometric and Frequency Calibration of EOS-Aura TES Infrared Spectra A33A-0121

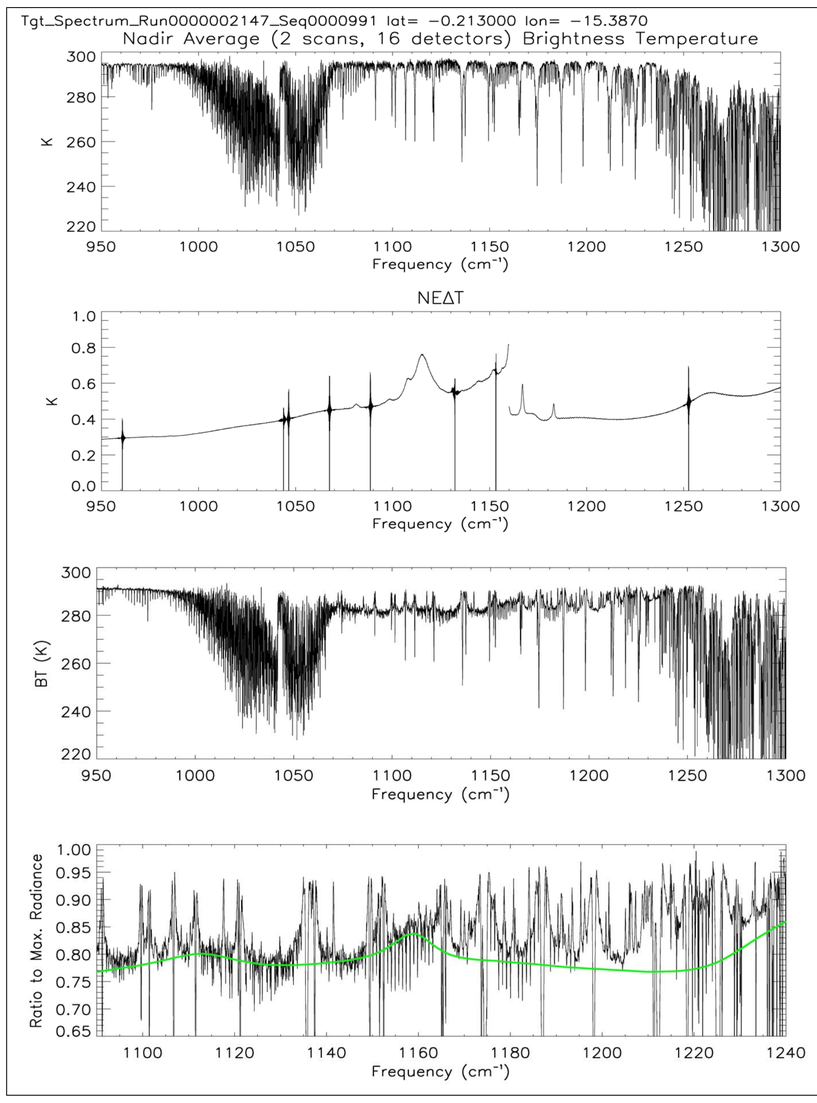
JPL Raytheon

tes

TES CALIBRATION RESULTS



LIMB spectra for 57.6° S, 128.9° E, taken 9/20/2004. Spectra clearly show features due to Nitric Acid and CFC 11,12, with distinct altitude dependence. O_3, CO_2 and H_2O spectral lines are also visible. The surface Is obscured by clouds.



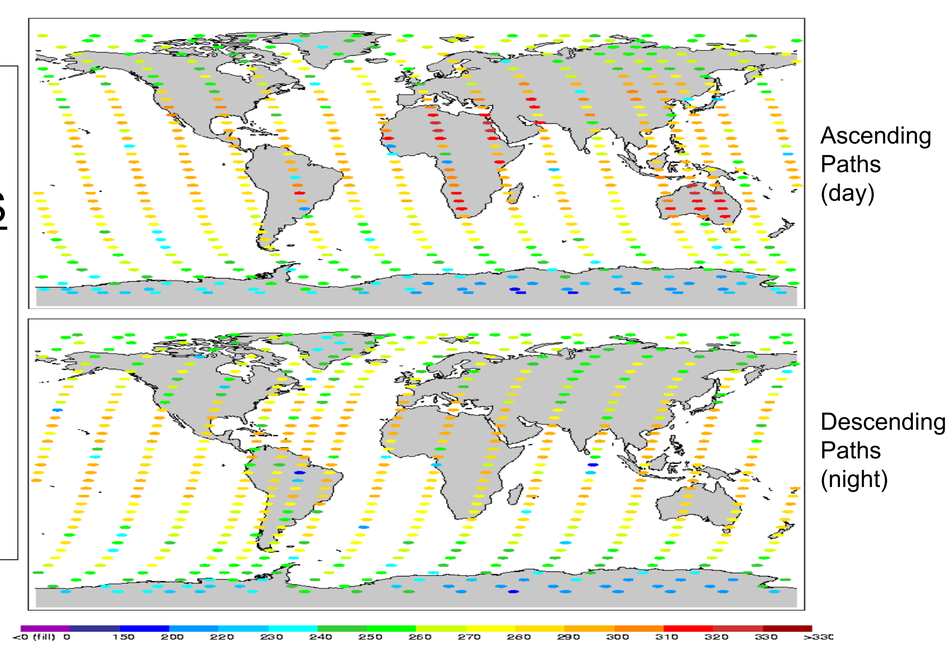
NADIR OCEAN SPECTRUM

with estimated NEΔT (Noise Equivalent Delta Temperature) and known instrument spikes shown in lower the panel.

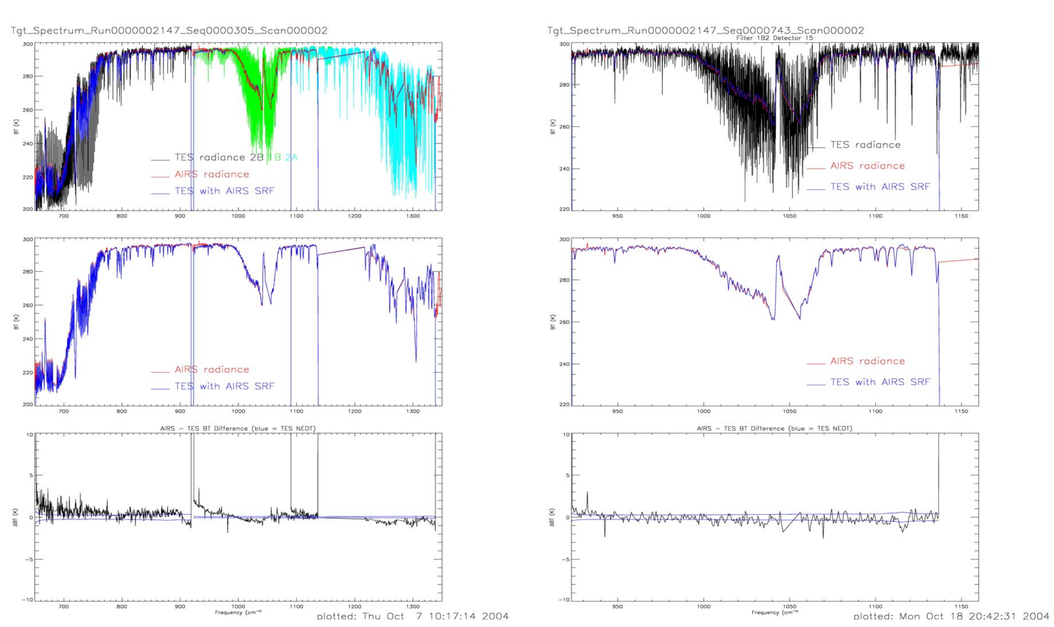
NADIR AFRICAN DESERT SPECTRUM AT NIGHT

Taken over Mauritania, 19.57° N, 11.07° W, 9/20/2004. Tropospheric H_2O and CH_4 are observed in emission in the spectral region with lower surface emissivity due to silicates in the soil. Green curve shows an example of spectral emissivity for desert sandstone. (from the ASTER spectral library)

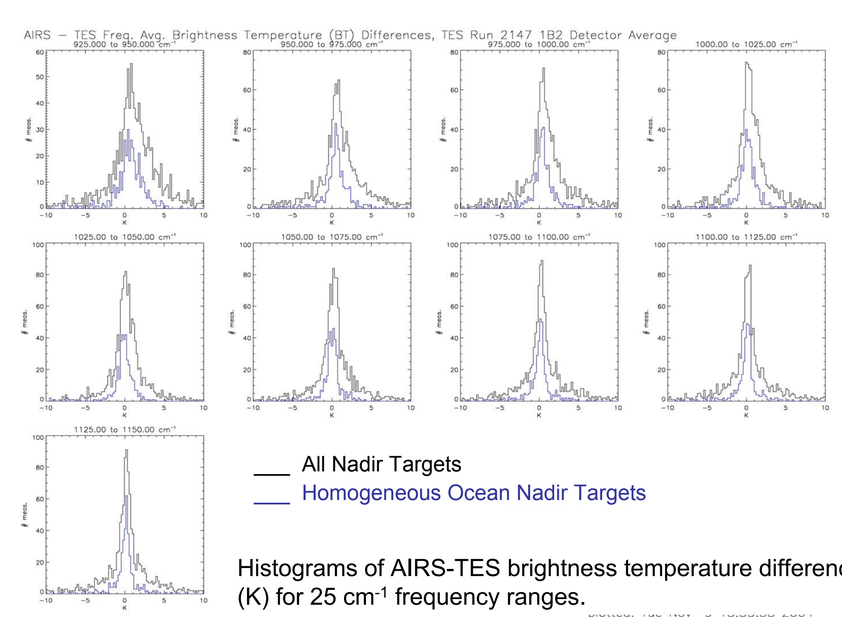
NADIR BRIGHTNESS TEMPERATURES (near 10 μm) for a 16-orbit Global Survey taken 9/20/2004. Colors indicate temperature in K.



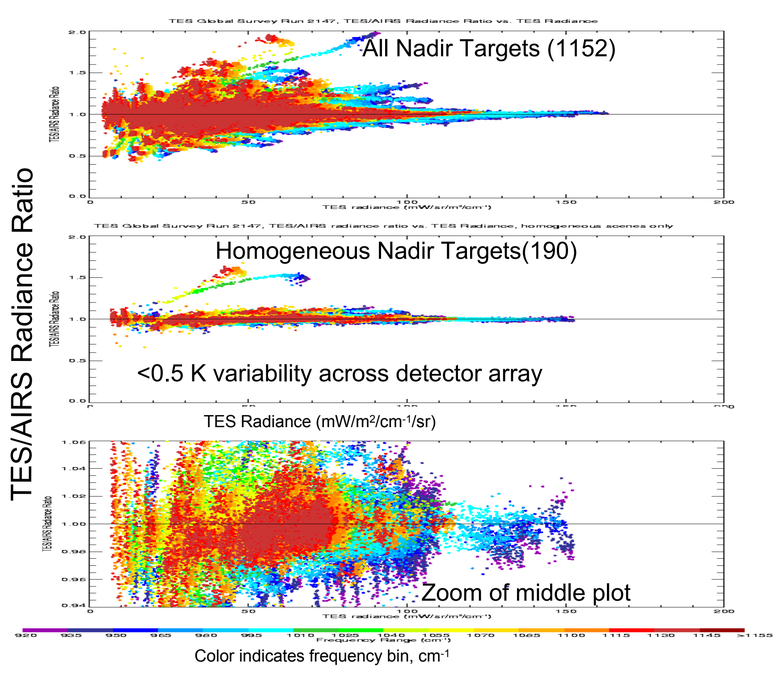
TES-AIRS RADIANCE COMPARISONS



Comparisons ofTES and AIRS observed brightness temperature where TES radiances have been convolved with the AIRS spectral response function (SRF).



Histograms of AIRS-TES brightness temperature differences (K) for 25 cm⁻¹ frequency ranges.



CONCLUSIONS

- Initial calibration results show reasonable agreement with AIRS data.
- Further algorithm refinement is in progress to reduce systematic errors due to:
  - phase alignment of calibration and target scans
  - time dependence of instrument response and offset
  - view dependence, if detected.
- Beta release for TES L1B data will be in early 2005 at the Langley DAAC: http://eosweb.larc.nasa.gov/

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

NASA

http://tes.jpl.nasa.gov