NIST TXR Validation of Scanning HIS Radiances and a UW-SSEC Blackbody

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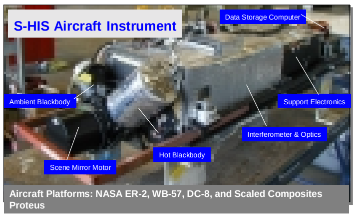
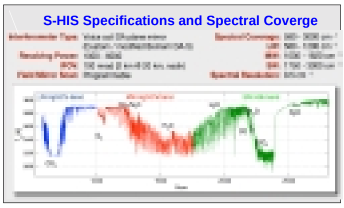
Overview

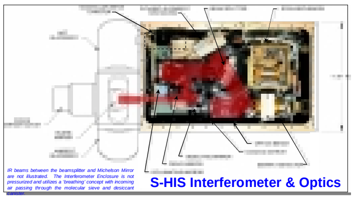
The ability to accurately validate infrared spectral radiances measured from space by direct comparison with airborne spectrometer radiances was first demonstrated using the Scanning High-resolution Interferometer Sounder (Scanning HIS) aircraft instrument flown under the AIRS on the NASA Aqua spacecraft in 2002. Subsequent comparisons in 2004 and 2006 have also demonstrated successful comparisons that now span a range of conditions, including arctic and tropical atmospheres, daytime and nighttime, ocean and land surfaces. These results show brightness temperature differences that often approach 0.1 K over much of the spectrum. This close agreement shows great progress, is encouraging for achieving consistent remote sensing applications, and will even be meaningful for sensitive climate applications, if the absolute calibration of the Scanning HIS can be convincingly proven to this level. Then the Scanning HIS will provide a direct link between NIST and on-orbit observations. With this goal, new tests of Scanning HIS absolute calibration have been conducted using the NIST transfer radiometer (TXR). The TXR was used to accomplish a more direct connection to the Blackbody reference sources maintained by NIST than the normal traceability of blackbody temperature scales and paint emissivity measurements.

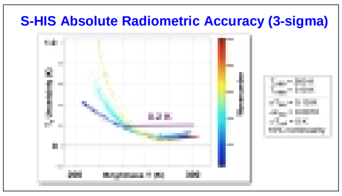
Two basic tests were conducted: (1) comparison of radiances measured by the Scanning HIS to those from the TXR, and (2) reflectivity measurements of a UW-SSEC blackbody by using the TXR as a stable detector. The radiance comparison involved the Scanning HIS and the TXR each observing a highly stable (and accurate) Atmospheric Emitted Radiance Interferometer (AERI) blackbody over a wide range of temperatures (227 to 290 K). The Scanning HIS was operated at a typical flight temperature, with the optical bench at about 260 K. Brightness temperature differences between the TXR and the Scanning HIS were found to be, on average, less than 40 mK. The AERI blackbody reflectivity measurement used a heated tube placed between the TXR and the Blackbody (axis co-aligned with the TXR viewing axis and the normal to the center of the AERI blackbody aperture). The tube was heated to about 100 K over the ambient environment of about 225 K. The measured reflectances were better (lower) that predicted, and within the predicted uncertainty of the original estimates. Preliminary results from both tests are very promising for confirming and refining the expected absolute accuracy of Scanning HIS.

Scanning High-resolution Interferometer Sounder (S-HIS)





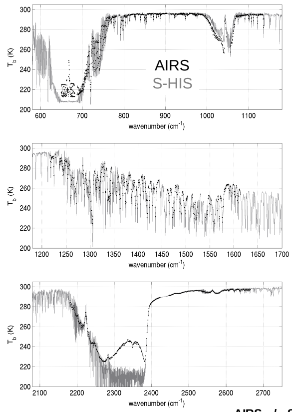


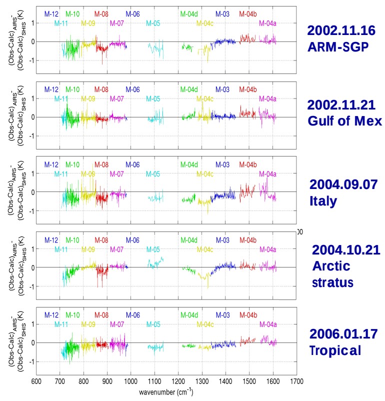


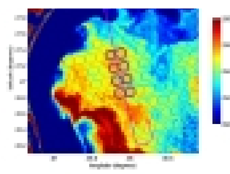
The S-HIS employs a customized commercial interferometer (DA5 from Bomem, Inc, Quebec), with dynamically aligned plane mirrors and a UW developed Michelson mirror drive. The spectral characteristics of the measurements are very well known and stable because of the use of a HeNe laser to control optical delay sampling. The radiometric calibration of the S-HIS is accomplished by periodically viewing two high emissivity, uniform temperature blackbody references, that provide the responsivity and offset parameters needed to convert measured spectra to radiances.

The S-HIS has continuous spectral coverage from 3.3 to 16.7 mm at 0.5 cm-1 resolution. This coverage is divided into three bands with separate detectors (two PC HgCdTe and one InSb) to achieve the required noise performance. The longwave band provides the primary information for temperature sounding for cloud phase and particle size. The midwave band provides the primary water vapor sounding information and further cloud property information. The shortwave band provides information on cloud reflectance and augments sounding information. The 3-sigma absolute radiometric uncertainty for the S-HIS presented in the lower figure.

S-HIS Aircraft Instrument Comparisons With AIRS







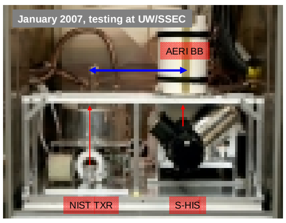
AIRS / S-HIS measured brightness temperature comparisons (without accounting for viewing angle) are shown at left for the November 21, 2002 Gulf of Mexico underflight case. At right several different AIRS / Scanning-HIS comparisons are shown using the Double Difference Approach, where the Scanning-HIS observed minus calculated is differenced from the AIRS observed minus calculated.

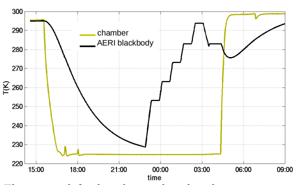
The results are remarkably good, and generally within the Scanning-HIS error budget. The cases include Tropical to Arctic conditions and extend over a significant portion of mission life. The results provide traceable uncertainties that form the basis for AIRS to be used for satellite cross-calibration. Recent underflights of IASI by Scanning HIS also show excellent agreement.

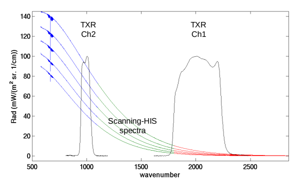
NIST TXR Intercomparison Testing at the University of Wisconsin

S-HIS / TXR Radiance Intercomparison

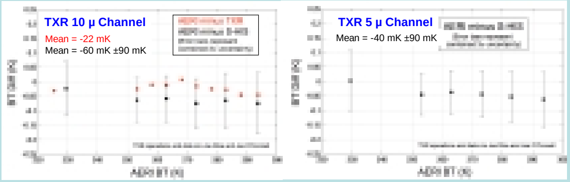
End-to-end radiance evaluations of the S-HIS were conducted at UW-SSEC, under flight-like conditions using the NIST TXR in a temperatrue chamber. A UW developed AERI Blackbody was run at various temperatures and positioned between the NIST TXR and the S-HIS. Calculated radiances from the AERI BB were compared with measured radiances from the NIST and TXR. These intercomparison measurements provide the basis for satellite validation analyses that are traceable to the NIST radiance scale.







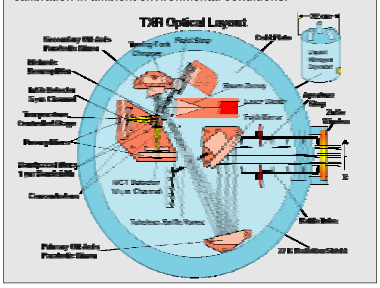
The upper left plot shows the chamber temperature being held at close to flight ambient levels near 225 K, while the AERI Blackbody is sequentially raised in temperature up to 295 K. The upper right plot shows five Scanning HIS spectra corresponding to five different blackbody temperatures. The spectral response function of the TXR at 5 and 10 μ is also shown.

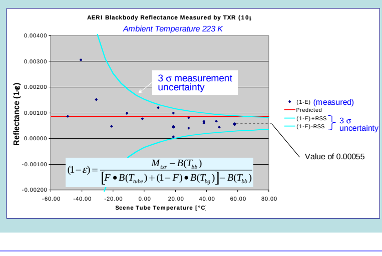


The graphs above plot the difference between the predicted AERI BB radiance and the measured S-HIS radiance (at both 5 and 10 μ) and the measured TXR radiance at 10 μ (the TXR 5 μ analysis is not yet completed). At 10 μ the differences between the NIST TXR and Scanning-HIS are in excellent agreement - on the order of 40 mK.

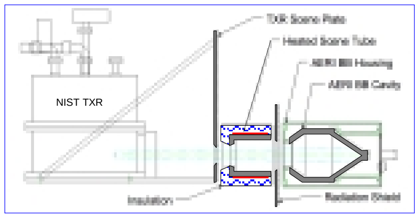
NIST Transfer Radiometer

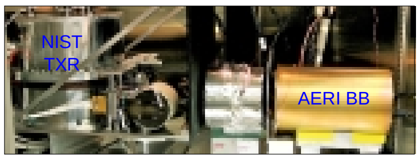
The Thermal-infrared Transfer Radiometer (TXR) was developed as part of a multi-year calibration program between the NASA EOS Project Science Office and the NIST Optical Technology Division. The TXR is a two-channel portable cryogenic filter radiometer for providing thermal-infrared scale verifications of large-area calibration sources. The goal is to provide in-situ measurements of the radiance that the flight instrument actually sees during its chamber calibration. NIST Water Bath Blackbody Used for TXR calibration in ambient environmental conditions.





AERI BB Reflectance Measurement With TXR





$$M_{txr} = \varepsilon \bullet B(T_{bb}) + (1-\varepsilon) \bullet [F \bullet B(T_{tube}) + (1-F) \bullet B(T_{bg})]$$

direct radiance from BB — reflected radiance from BB

For the reflectance measurement of the AERI Blackbody, the NIST TXR, a Heated Scene Tube, the Blackbody, and a Radiation Shield were placed in a temperature chamber that was maintained at -50 °C. The TXR was configured to view only the Blackbody (no view to the Scene Tube). The Scene tube temperature was sequentially raised in a stair-step fashion to 60 °C during which the TXR measured radiance was recorded. This radiance is the sum of the terms in the equation above, where ε is the AERI blackbody radiance, Tbb is the blackbody temperature, Tbg is the background temperature, Ttube is the Scene Tube temperature, and F is the radiation view factor from the blackbody to the Scene Tube.

The results from the UW analysis of these measurements for the 10 μ TXR Channel are plotted at left, with reflectance (1-ε) plotted against Scene Tube temperature. The 3-sigma uncertainty is shown in the plot, along with the predicted AERI Blackbody reflectance value. As shown at left, (1-ε) at 10μ is 0.00055. At 5μ (not shown), (1-ε) was found to be 0.00033.