A TOOL FOR THE 2003 ROVER MINI-TES: DOWNWELLING RADIANCE COMPENSATION USING INTEGRATED LINE-SIGHT SKY MEASUREMENTS. B. T. Greenhagen\textsuperscript{1}, L.E. Kirkland\textsuperscript{2,3}, T. Grabowski\textsuperscript{3}, and E. S. G. Rainey\textsuperscript{4}, \textsuperscript{1}Washington University, St. Louis MO, beng@levee.wustl.edu; \textsuperscript{2}Lunar and Planetary Institute, Houston TX, kirkland@lpi.usra.edu; \textsuperscript{3}The Aerospace Corporation, Chantilly VA; \textsuperscript{4}California Institute of Technology, Pasadena CA, emma@gps.caltech.edu.

Introduction: The 2003 Mars Exploration Rover science strategy is to identify promising targets using the visible/near-infrared imaging Pancam and the thermal infrared spectrometer Mini-TES. The rover would then traverse to those targets for more detailed examination. Team members will select geologic targets from target morphology and color using Pancam, and target mineralogy using Mini-TES. This strategy requires low ambiguity, near real-time interpretations of Pancam and Mini-TES data.

Field spectrometer (i.e. Mini-TES) measurements differ significantly from both laboratory and airborne/satellite (i.e. Mars Global Surveyor TES) measurements. The primary difference in ground-based measurements is that reflected atmospheric downwelling radiance can significantly complicate the result. Here we show compensation strategies, including a new method that relies entirely on line-sight sky measurements.

Data: Our instrumentation is the only thermal infrared hyperspectral imager used in the field, and it measures with the highest fidelity to the Mini-TES of any field instrumentation available. We use Model 100 (M100) Block Engineering Fourier transform infrared interferometers in raster-scanning configurations. Table 1 compares the instruments.

<table>
<thead>
<tr>
<th></th>
<th>M100 \cite{1}</th>
<th>Mini-TES \cite{2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOV (mrad)</td>
<td>9</td>
<td>8 or 20</td>
</tr>
<tr>
<td>Sampling (cm\textsuperscript{-1})</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Range (µm)</td>
<td>7.5 – 13.5</td>
<td>5-25</td>
</tr>
<tr>
<td>Height (m)</td>
<td>2-3</td>
<td>1.4</td>
</tr>
</tbody>
</table>

FOV=field of view, sampling=spectral sampling interval, range=spectral range, height=height of FOV

Downwelling Radiance: Reflected downwelling radiance is the thermal energy radiated onto a target by all objects in a hemisphere surrounding the target, including topography and atmospheric gases and aerosols. Downwelling radiance causes the spectral character of the target to be effectively larger (i.e. higher radiance, higher brightness temperature, etc.) relative to the expected spectrum (see Figure 1). The significance of the downwelling radiance component differs with the environment of measurement. Indeed, for relatively cold targets and/or relatively warm (dusty) atmospheres downwelling radiance compensation is much more important than for relatively warm targets and/or relatively cold (dust-free) atmospheres.

![Figure 1: Effect of downwelling radiance](image)

Figure 1: Effect of downwelling radiance. The top trace shows the field spectrum uncorrected for downwelling radiance \cite{1}. The middle trace shows the same data corrected for downwelling radiance \cite{1}. The lower trace is a typical laboratory spectrum used to identify field measurements \cite{3, "quartz1.c"}. Note the apparent band near 1050 cm\textsuperscript{-1} in the uncorrected trace (arrow). Atmospheric bands cause the fine structure in the field spectra.

Textural effects. The texture of the targets dictates how one must correct for downwelling radiance. There are two endmembers, specular and diffuse. Smooth ( specular) targets have a singular surface and thus a single angle of incidence. These materials are only impacted by the downwelling radiance of a single point and require one light-sight measurement for downwelling compensation. However, from the spectrometer’s perspective each specular target will have a different angle of incidence, therefore, each target will require a unique line-sight measurement for downwelling correction. Rough (diffuse) targets have a multi-faceted surface and thus many different angles of incidence. These materials are imparted by the downwelling radiance of many points and require a hemispherical downwelling measurement (a measurement of the relative contribution of all points in the target surface’s hemisphere). The hemispherical downwelling can be readily measured using a high reflectance, rough-surfaced target of known spectral signature (i.e. a sandblasted aluminum plate). Fortunately, most geologic targets are predominately diffuse (especially when coated with dust) and have only a minor specular
A notable exception is desert varnish, which has a strong specular component [4].

**Simple Integrated Sky Method:** We have developed a new method (simple integrated sky method) of compensating for hemispherical downwelling radiance in absence of a known diffuse target. For targets in open terrain (i.e. not next to a cliff), the sky is the predominant source of downwelling radiance. The hemispherical downwelling can be calculated by modeling the thermal radiance of the sky. Assuming a homogeneous sky (clouds-free), one can effectively model the hemispherical downwelling by extrapolating and summing the relative contributions of line-sight measurements of the sky.

**Procedure.** Through analyzing line-sight measurements of the sky, we have found that for a given wavenumber, the plot of radiance vs. latitude is continuous curve (see Figure 2). The radiance value for each latitude is then weighted by extrapolating the area for each latitude around the hemisphere (see Figure 3). Next, the weighted radiance values are summed to determine a total radiance value for the wavenumber. This process is repeated for each wavenumber.

**Results.** We have found the simple integrated sky method to be a satisfactory technique for hemispherical downwelling compensation for a diffuse target. Figure 4 shows a comparison of compensation methods.

**Implications for Mini-TES:** It is unclear whether or not downwelling radiance will be a significant factor on Mars. The primary impact will be for the following cases: (1) wavelengths with lower target radiance; (2) colder target temperature; (3) warmer atmospheric conditions (e.g., higher dust loading, clouds). If so, Mini-TES data will need compensation for downwelling radiance to attain the best result. The rover does not carry a high reflectance diffuse calibration target so the correction would need to be made using line-sight measurements of the sky.

**Conclusions:** Our field experience has made it clear that downwelling radiance is a significant problem in some cases. The simple integrated sky method gives us a valuable tool to help correct for hemispherical downwelling when a high reflectance diffuse calibration target is not available. The simple integrated sky method is a simple solution to a problem that otherwise requires a complex model. While adequate for diffuse targets in open terrain, the simple integrated sky method will be less effective for targets in areas of high relief and targets with strong specular components. Further development and testing of downwelling radiance compensation techniques is required.

![Figure 3: Weighting the latitudes.](image3.png)

![Figure 4: Comparison of Compensation Methods.](image4.png)