TESTING THE SENSITIVITY OF ATMOSPHERIC RETRIEVALS FOR INFRARED INSTRUMENTS IN MARS ORBIT C. A. Wolfe[1], C. S. Edwards[1], and M. D. Smith[2], [1]Northern Arizona University, Flagstaff, AZ 86011; cw997@nau.edu, [2]NASA Goddard Space Flight Center, Greenbelt, MD 20771

Introduction: Since the 1960's, dozens of robotic spacecraft have explored and mapped the surface of Mars. Together, these missions have sent back hundreds of terabytes of data, allowing the scientific community to make great strides in understanding not only the surface geology and topography, but the atmosphere and climate of Mars as well. While our understanding of the Martian atmosphere has improved dramatically, the vast majority of this knowledge has come from Sun-synchronous orbiters like MGS, Mars Odyssey, and MRO. As a result, local time coverage has been relatively limited

Diurnal and seasonal variations are key quantities to consider for the retrieval of dust and water-ice optical depth from thermal-IR spectra, both of which influence the transfer of energy from the lower-middle atmosphere to the upper atmosphere [1]. TES aerobraking observations from MGS have provided a nearly complete diurnal coverage over a range of latitudes and seasons [2], but future missions will provide even greater coverage.

Context: In Earth and planetary science, spatially-resolved spectroscopy is arguably the most powerful technique available for retrieving the characteristics of planetary surfaces and atmospheres via remote sensing [3]. To assess the sensitivity of atmospheric retrievals from an infrared spectrometer in Mars orbit to changes in the physical and chemical state of the atmosphere/surface, we generate synthetic spectra using both climate and radiative transfer models.

To generate synthetic spectra, we require information on the physical and chemical state of the atmosphere and surface, such as the horizontal and vertical distributions of surface and atmospheric temperature, pressure, trace gas concentration, dust optical depth, surface albedo, as well as information on the how the surface emits/reflects light. The latest version of the Mars Climate Database (MCD v5.3) [4] [5] is used to obtain the aforementioned parameters.

Methodology: To understand the influence footprint sub-sampling might have on a disk-integrated spectra, root mean square (RMS) error in radiance is computed for each synthetic observation. Taking the observations with footprints sub-sampled using 2,048 pixels to be "truth" and all other observations as modeled retrievals, RMS error is computed, providing us with a quantitative description of the accuracy of the retrieved disk-integrated atmospheric spectra.

In order to test the sensitivity of retrievals to changes in the state of the atmosphere/surface, synthetic observations are produced for various orbital configurations. This synthetic data includes a set of "truth" observations as well as a series of observations that vary the number of sub-sampled pixels within each footprint. For this study we assume the spacecraft is in an elliptical orbit, providing complete global coverage of Mars, and the ability to investigate both large ($\sim$ 300km) and small ($\sim$ 100km) footprint sizes. Additionally, various times of day based on the sub-spacecraft point (LST = 0, 6, 12, and 18) are probed.

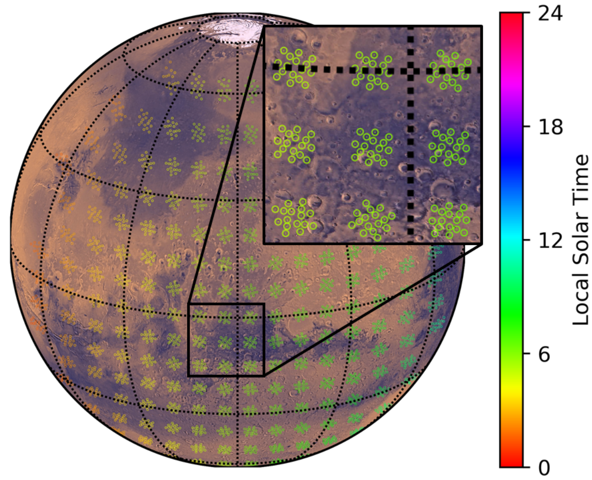

Figure 1: Synthetic observation for an infrared spectrometer in Mars orbit at a local solar time of 0600 hours, where individual footprints have been sub-sampled to 16 pixels.

Footprints are sub-sampled by splitting them into quadrants and applying a stochastic blue-noise point distribution pattern such that each footprint is 4-way rotationally symmetric. The "truth" observations are then downsampled to 1,024, 512, 256, etc. pixels to represent different retrieval resolutions. Figure 1 provides an example of a synthetic observation sub-sampled at 16 pixels per footprint at periapsis and 0600 hours.

Once synthetic orbital observations have been generated, vertical temperature profiles are obtained from the Mars Climate Database (MCD) using a high-resolution mode (32 pixels/degree). This process involves producing a vertical temperature profile with gas mixing ratios, dust optical depth, etc. for each sub-sampled pixel in each individual footprint of an observation. Various dust and solar radiation (i.e low/high atmospheric dust abundance, solar minimum/maximum) scenarios are utilized to investigate the impact these forcings have on the disk-integrated spectra.

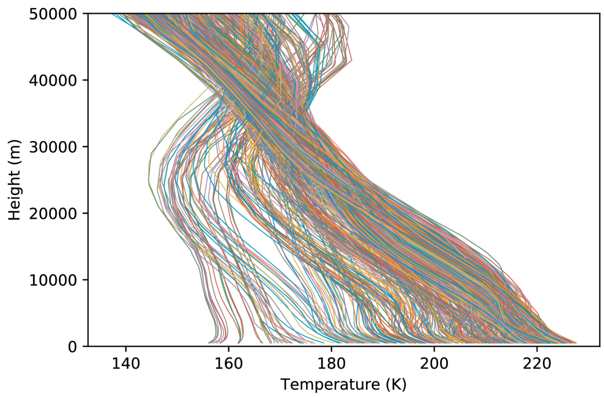

Figure 2: Vertical temperature profiles for each pixel (denoted by various colors) in a sub-sampled footprint from the synthetic observation shown in Figure 1.

The vertical temperature profiles described above and depicted in Figure 2 are used as input in the Spectral Mapping Atmospheric Radiative Transfer Model (SMART) to generate synthetic spectra for each sub-sampled pixel in each individual footprint of an observation. SMART is a multi-stream, multi-level, spectrum-resolving (line-by-line) multiple-scattering algorithm to generate the high-resolution synthetic spectra of planetary atmospheres [6]. SMART employs a variety of parameters to solve the equation of radiative transfer, including the number of discrete zenith angles (streams) used as well as the wavenumber resolution.

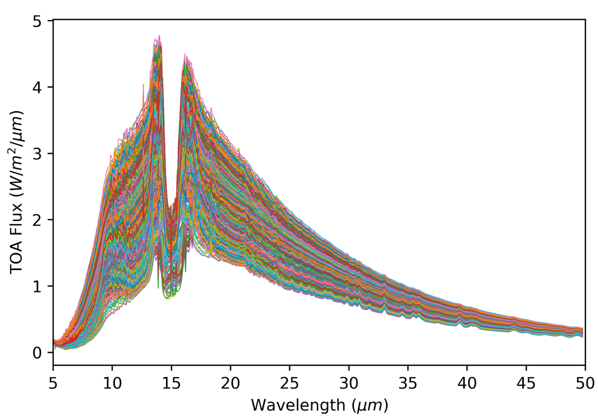

Figure 3: Top of atmosphere thermal-IR spectra for each pixel (denoted by various colors) in a sub-sampled footprint from the synthetic observation shown in Figure 1.

A comprehensive analysis is conducted whereby the number of streams are varied. Starting with a total of 16 streams (8 upwelling, 8 downwelling) and incrementally decreasing to a total of 4, we aim to characterize the number of streams needed to adequately identify changes in spectral features. Wavenumber resolution is also varied, starting at $0.01cm^{-1}$ and decreasing to $10cm^{-1}$, allowing us to establish the minimum wavenumber resolution necessary to observe unique spectral features.

Preliminary Results: The synthetic spectra in Figure 3 show a set of features that are characteristic of the CO_2 atmosphere of Mars. In the thermal-IR, the spectrum is dominated by the ν_2 fundamental vibrational frequency of CO_2, centered around 15μm, and spanning the range from ∼12 to 19μm. On opposite sides of the 15μm band are sharp peaks that are perhaps indicative of the temperature inversion that occurs in many vertical profiles at 0600 hours. Some spectra also show a set of hot bands on the sides of the 15μm feature, arising from vibrational transitions originating from above the ground state. Other weaker CO_2 absorption features can be seen around 10μm.

Water-vapor concentration in the Martian atmosphere is variable in space and time but is typically in the range of a few to several tens of precipitable microns [7]. While the spectral resolution isn't quite high enough to see the weak absorption from the ν_2 fundamental vibrational frequency of water vapor spanning the region 5-7.5μm, absorption of water vapor due to molecular rotation can be spotted at 30+μm.

With the exception of the features described above, the atmosphere of Mars is mostly transparent, and emission or reflected solar radiation from the solid surface can be observed over a wide spectral range. While we have not specifically included contributions from water-ice clouds in our model, the spatial and temporal variability of airborne dust is captured. Aerosol dust typically produces a broad silicate emission feature centered around 9.5μm, but given the time of day $(0600$ hours) explored in Figure 3, this feature is slightly muted and may even be in emission in some spectra.

References: [**1**] Sharaf O. et al., (2019) *LPI Contributions*, *2089*, 6058. [**2**] Badri K. M. et al., (2019) *AGU Fall Meeting Abstracts*, *P41B-3428*. [**3**] Tinetti G. et al., (2005) *Astrobiology*, *5*, 461-482. [**4**] Forget F. et al., (1999) *J. Geophys. Res.*, *104*, 24155-24175. [**5**] Millour E. et al., (2017) *EGU General Assembly Conference Abstracts*, 12247. [**6**] Meadows V. S. and Crisp D. (1996) *J. Geophys. Res.*, *101*, 4595-4622. [**7**] Clancy R. T. et al., (1996) *Icarus*, *122*, 36-62.