SPATIAL VARIABILITY OF CO AND CO₂ ON MARS FROM NEAR-INFRARED IMAGING SPECTROSCOPY; James F. Bell III (Planetary Geosciences, SOEST, University of Hawaii, Honolulu 96822) and David Crisp (JPL/Caltech, 4800 Oak Grove Dr., Pasadena CA 91109).

During the November 1990 opposition, we obtained 1.30-4.05 μm images and spectra of Mars from the NASA IRTF at Mauna Kea [1,2]. Our focus was on 0.9% spectral resolution and 100-200 km spatial resolution data in K-band (1.9-2.5 μm) in order to detect and spatially map atmospheric absorptions due to CO and CO₂ as well as surface and/or airborne dust mineral absorptions potentially due to clays [3] or possibly scapolite [4].

We extracted numerous relative reflectance spectra by ratioing different surface regions to the sub-earth point [2,5]. We have found (not surprisingly) that the observed spectral heterogeneity of martian atmospheric CO and CO₂ is well correlated with topography (areas of lower elevation have increased band depth), except for a few anomalous regions such as Lunae Planum and Solis Lacus where the correlation between CO and topography does not hold. Small absorption features were detected at 2.21 and 2.25 μm. Maps of the spatial variations of these bands show poor correlation with topography, and thus these features may be related to variations in surface mineralogy.

To further define the correlation between CO and CO₂ band depth variations and other variables, such as topographic elevation, albedo, and atmospheric dust content, we have created relative reflectance spectra by extracting profiles from the images at a nearly constant emission angle along an annulus of equal distance from the sub-earth point. This method effectively eliminates differences in absorption band depth due to atmospheric path length for areas of equal elevation. Some representative profiles are shown in Figure 1. The top panels show the ratio of calibrated DN values in two filters vs. position angle in degrees counter-clockwise from north. Thus, 0° position angle is the north pole, 180° is the south pole. The annulus profiles were taken at a radius of 0.9Rₘₚ. The bottom two panels show the Viking-derived topography and albedo along the same annulus profile as curves A-E. In spite of differences in resolution of the ground-based and spacecraft data, the comparison is nonetheless instructive.

For example, profile E shows the extracted ratio between 2.00/2.29 μm. The 2.00 μm image was taken near the center of the strongest martian CO₂ feature within K-band, while at 2.29 μm the martian atmosphere is basically completely transparent [6]. This profile basically mirrors that of the topography, as expected, since CO₂ is the dominant atmospheric component and is well-mixed. In fact, the largest deviations from the topography occur in the north polar region (position angles 310-360°) and in southeastern Tharsis (P.A. 30-50°), where condensates like the polar hood or orographic clouds are most likely to effect the observed CO₂ band depth. Profile (B), which is a ratio of a strong and a weak CO₂ absorption feature, also shows good overall correlation with topography. The CO₂ absorption coefficient is much higher at 2.00 μm than at 2.15 μm, and thus the brightness at 2.00 μm is modulated more severely than that at 2.15 μm by changes in elevation. Profile (A) shows the ratio between images taken on opposite wings of the strong 2.01 μm CO₂ band. The ratio is higher in the northern hemisphere than in most of the south; this could indicate that we can detect a minor broadening of the CO₂ band with temperature. It is unclear whether the temperature change is due to seasonal effects (the sub-earth latitude was -6.5°, Lₛ = 333°, late northern winter) or to the fact that the northern hemisphere at these sub-earth longitudes is dominated by bright regions while the south is mostly dark. Profile (C) shows a profile of the ratio between CO₂ and the strong 3-μm hydrate band. The enhanced ratios at both poles are apparently caused by the preferential distribution of atmospheric water vapor at polar latitudes [1,2], especially in the north where the UV-bright polar hood was observed during this time. Finally, profile (D) shows the ratio between the deepest martian CO₂ and CO bands [6]. There is a fair correlation between CO₂ and CO band depth and topography for much of the southern hemisphere, much like that in profile (E). However, in the region of P.A. 250°-80° the trend is absent or reversed. Some of this anomalous region overlaps the region in profile (E) that may be influenced by condensates, however there are large ranges of position angles where the behavior of CO appears unrelated to that of CO₂ or topography (i.e., 250°-300°; 0°-20°).

Clearly, our measurements have demonstrated that there is substantial spectral heterogeneity in the martian atmosphere and that it can be detected using state-of-the-art ground-based telescopic instrumentation even during "average" oppositions like 1990 (and 1993). Currently we are attempting to refine the calibration of these imaging spectroscopic data and to model our observed albedos using radiative transfer codes. Of particular importance will be models that vary the atmospheric dust loading, since this variable may help explain some of the anomalous and
intriguing results presented in our profiles (Figure 1). Initial results show that increasing the dust opacity from nominal values ($\tau = 0.15$) to $\tau = 0.3$ increases the computed ratios because the depth of the 2.00 $\mu$m CO$_2$ band is decreased as the increased dust scatters more radiation back to space before it can be absorbed. Thus, some of the regions of poor correlation between CO and CO$_2$ may be accounted for by regional variations in dust opacity.

FIGURE 1. Profiles of DN ratios obtained along an annulus of 0.9RMars. The ratios are between the wavelengths indicated. (A) Ratio between two images on the opposite wings of the strongest CO$_2$ feature within K-band. (B) Ratio between the strong 2.00 $\mu$m CO$_2$ feature and a weaker 2.15 $\mu$m CO$_2$ band. (C) Ratio between the strong CO$_2$ band and an image near the center of the broad and deep 3-micron hydrate feature. (D) Ratio between the strongest CO$_2$ and CO bands in K-band. (E) Ratio between the strong 2.00 $\mu$m CO$_2$ band and a "continuum" wavelength at which the martian atmosphere is transparent [6]. The bottom two panels show the topography and broadband solar albedo along these same annular profiles as obtained by Viking Orbiter (PDS data). The large spike in the topography data is Olympus Mons, which was apparently not resolvable in our ground-based images. The sub-earth point latitude was $-6.5^\circ$, and the sub-earth longitude was near 70°. Thus, from the north pole the profiles travel through Tempe, Tharsis (P.A. 40-80°), Claritas, Bosphorus (140-160°), Australe, Noachis, Erythraeum, Chryse (260-300°), and return to the pole near Acidalium. Additional details of the observing conditions, instrumentation, and data reduction are given in [1,2].