

**CRISM OBSERVATIONS OF WATER VAPOR AND CARBON MONOXIDE.** Michael D. Smith<sup>1</sup>, Michael J. Wolff<sup>2</sup>, R. Todd Clancy<sup>2</sup>, and the CRISM Science Team. <sup>1</sup>NASA Goddard Space Flight Center (Greenbelt, MD, 20771 USA; Michael.D.Smith@nasa.gov), <sup>2</sup>Space Science Institute (Boulder, CO, USA).

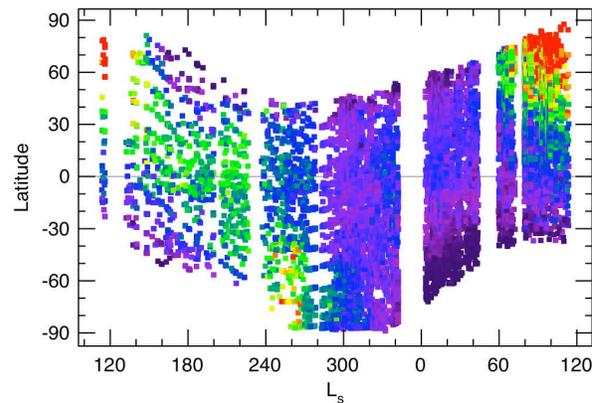
**Introduction:** Near-infrared spectra returned by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM, [1]) on-board the Mars Reconnaissance Orbiter (MRO) contain the clear spectral signature of several atmospheric gases including carbon dioxide (CO<sub>2</sub>), water vapor (H<sub>2</sub>O), and carbon monoxide (CO). Here we describe the seasonal and spatial mapping of water vapor and carbon dioxide for one full Martian year using CRISM spectra.

**CRISM Observations:** Two main types of observations are taken by CRISM. Emission Phase Function (EPF) observations are taken at full spectral resolution at selected locations of interest. Multispectral observations are taken with a reduced set of wavelengths (chosen to maximize information content) to provide global mapping coverage. Both types of observations are useful for the retrieval of atmospheric gas abundance.

As the main constituent of the atmosphere, carbon dioxide has numerous strong spectral signatures that are readily apparent in CRISM spectra, including prominent bands centered near wavelengths of 1.4, 2.0, and 2.7 microns. Of these, we choose to use the band centered near 2.0 microns for our retrieval of CO<sub>2</sub> abundance (or surface pressure) because it provides the best balance between having sufficient strength to provide good signal while not being so strong that the band is saturated. The major spectral signatures caused by water vapor are centered near 1.35, 1.9, and 2.6 microns. Our experience with the CRISM data is that the band at 2.6 microns provides the most reliable retrieval of water vapor abundance. Carbon monoxide has a weak, but readily apparent spectral signature centered near 2.35 microns.

**Retrieval:** Radiative transfer modeling of CRISM spectra has been used to retrieve the column abundance of water vapor and carbon monoxide. We compute synthetic spectra using the correlated-k approximation for gas absorption [2] and a discrete-ordinates approach [e.g. 3] to model aerosol scattering and the solar beam. Gas abundance is varied to provide the best fit in a least-squares sense between the computed and observed spectrum in the spectral region of the gas absorption. Aerosol optical depth can be either estimated using climatological values observed by Mars Global Surveyor TES [4], concurrent observations by Mars Odyssey THEMIS, or by direct retrieval from CRISM Emission Phase Function (EPF) observations [5]. Here we have used concurrent THEMIS observations.

**Results:** Well over 10,000 CRISM hyperspectral (full-spectral resolution) nadir observations have been taken over the first full Martian year of operations. These data have been used to map the column abundance of atmospheric gases as a function of season (L<sub>s</sub>), latitude, and longitude. Figure 1 shows an example displaying the seasonal and latitudinal dependence of water vapor as observed in CRISM observations.



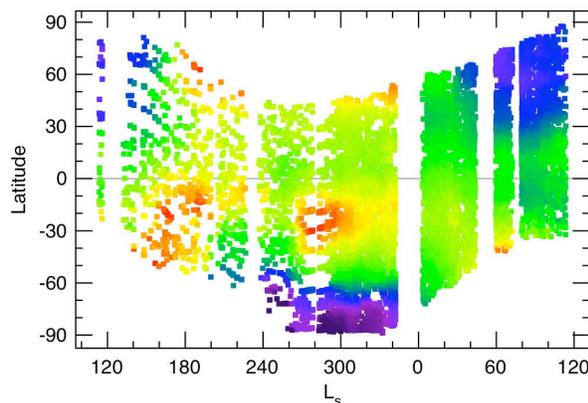
**Figure 1.** Retrieved water vapor column abundance as observed using CRISM hyperspectral observations. The red colors correspond to a column abundance of 30 pr- $\mu\text{m}$  or greater, green corresponds to roughly 15 pr- $\mu\text{m}$ , and purple corresponds to less than 5 pr- $\mu\text{m}$ . Peak water vapor abundance in northern summer is about 60 pr- $\mu\text{m}$ .

The peak in water vapor abundance over the northern summer pole, and its subsequent decrease and movement to the south are similar to what was observed by TES in previous martian years [6]. However, the southern hemisphere spring/summer maximum shows very different behavior than has been observed previously by TES. In CRISM observations (which cover Mars Years 28 and 29), southern hemisphere water vapor abundance shows a significantly earlier increase than that observed in previous years by TES. CRISM observed increased water vapor in the south beginning at L<sub>s</sub>=230° compared to L<sub>s</sub>=260° observed by TES. Furthermore, CRISM observations show no south polar maximum at L<sub>s</sub>=280°–300° as has been consistently observed by TES. The early appearance of the southern hemisphere summertime maximum in water vapor preceded the onset of a planet-encircling dust storm event at about L<sub>s</sub>=270°, and dust optical depth was not high at high southerly latitudes during

$L_s=280^\circ-300^\circ$ , so the observed differences in the water vapor cannot be explained as an artifact caused by the large dust storm. The overall abundance of water vapor during  $L_s=330^\circ-60^\circ$  was also somewhat lower in the CRISM observations than in the TES observations.

The spatial variation of water vapor as observed by CRISM (not shown in Fig. 1) follows the expected positive correlations with surface pressure and albedo, and negative correlation with thermal inertia [7]. CRISM observations of  $O_2$  singlet delta emission, an excited state of oxygen produced by photodissociation of ozone, show a strong anticorrelation with water vapor abundance, consistent with previous results.

Figure 2 shows the seasonal and latitudinal dependence of carbon monoxide mixing ratio as observed in CRISM observations. Results have been smoothed with a sliding-box average  $15^\circ$  wide in latitude and  $L_s$  to improve signal-to-noise. The relative maximum at  $L_s=270^\circ-300^\circ$  and  $10^\circ-40^\circ$  S latitude is likely an artifact caused by unreliable carbon monoxide retrievals during the most optically opaque part of a planet-encircling dust storm.



**Figure 2.** Retrieved mixing ratio of carbon monoxide as observed using CRISM hyperspectral observations. Smoothing ( $15^\circ$  in latitude and  $L_s$ ) has been performed on the data. The red colors correspond to a mixing ratio of 1100 ppm or higher, green corresponds to roughly 700 ppm, and purple corresponds to 200 ppm. The local maximum at  $L_s=280^\circ$  and  $25^\circ$  S latitude is likely an artifact of a planet-encircling dust storm.

The mixing ratio of carbon dioxide shows the clear seasonal signal of depletion over the summer pole and likely enrichment over the winter pole. A similar seasonal dependence has been observed in argon mixing ratio [8] and has been predicted for non-condensable gases by MGCM models [e.g. 9, 10]. Presumably, the observed summertime depletion in CO mixing ratio

occurs as  $CO_2$  is released into the atmosphere by the sublimating seasonal polar caps. The magnitude of this depletion and its seasonal and latitudinal dependence provide important information about transport dynamics during this period.

The annual, global mean mixing ratio is about 700 ppm, but there are substantial variations. The mixing ratio reaches a minimum of about 200 ppm in the southern summer high latitudes and about 400 ppm in the northern summer high latitudes. The peak enrichment values observed are about 1100 ppm, but higher values likely exist near the winter poles. Those regions cannot be observed by CRISM, which relies on reflected sunlight.

**References:** [1] Murchie, S. L. et al. (2007) *JGR*, 112, doi:10.1029/2006JE002682. [2] Lacy, A. A. and Oinas, V. (1991), *JGR*, 96, 9027–9063. [3] Thomas, G. E. and Stamnes, K. (1999), *Radiative Transfer in the Atmosphere and Ocean*, Cambridge Univ. Press. [4] Smith, M.D. (2006), *Proc. of the 2nd Workshop on Mars Atmosphere Modeling and Observations*. [5] Wolff M. J. (2007) *7th Intl. Conf. on Mars* abstract. [6] Smith, M. D. (2004) *Icarus*, 124, 586–597. [7] Smith, M. D. (2002) *JGR*, 107, doi:10.1029/2001JE00001522. [8] Sprague, A. L., et al. (2007) *JGR 112 E03S02*, doi:10.1029/2005JE002597. [9] Nelli, S. M., et al. (2007) *JGR 112 E08S91*, doi:10.1029/2006JE002849. [10] Forget, F., Montabone, L., and Lebono, S. (2006), *Proc. of the 2nd Workshop on Mars Atmosphere Modeling and Observations*.