High Spatial Resolution Visible Wavelength Orbital Multispectral Imaging of Mars from the *Mars Odyssey* THEMIS-VIS Instrument.

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Introduction. The Mars Odyssey Thermal Emission Imaging System Visible Imaging Subsystem (THEMIS-VIS) [1,2] has acquired and downlinked more than 59,000 image sequences (~205 GBytes of data) since the spacecraft entered Mars orbit in February 2002. We have analyzed most of the > 8200 multispectral image sequences acquired by VIS and find that visible-wavelength spectral variability at ~100 meter scales that is likely to be related to compositional or mineralogic variability is rare and subtle in the ~3.5% of the martian surface sampled so far in color at this scale.

Instrumentation. THEMIS-VIS is a fixed nadir-pointed CCD imaging camera with 5 narrowband filters (425, 540, 654, 749, and 860 nm) bonded directly to the CCD. Each filter covers an approximately 1024x192 pixel region of the detector and allows only that specific wavelength to be imaged for those pixels. The filters are aligned such that multispectral coverage of the surface can be obtained using spacecraft groundtrack motion (traveling from north to south on the afternoon side of the orbit) to consecutively expose each surface region in view to each of the THEMIS-VIS filters. The imaging cadence and exposure durations are timed so that the desired region is covered by the desired filters with a small amount of spatial overlap. Images at the five THEMIS-VIS wavelengths can be commanded to be acquired in one of three spatial resolution modes: 18, 36, and 72 m/pixel. Spatial resolution, spectral coverage, and spatial coverage must all be traded off against each other for a given spacecraft orbit, given the 3.8 Megabyte data volume capacity of the THEMIS-VIS onboard data buffer. For example, a full-resolution (18 m/pixel) 5-color THEMIS-VIS spectral sequence can cover a surface region only about 10 km along-track by 18 km cross-track. Reducing the spatial resolution to 36 m/pixel, however, extends the along-track coverage to more than 50 km for 5-band imaging. These parameters can also be traded against each other within broader observational campaigns over longer time periods focused on morphologic or color imaging. Additional details on the instrumentation and observing strategy for THEMIS-VIS can be found in [1,2].

Table 1. THEMIS VIS Images Acquired in Different Bands and Summing Modes Between February 2002 and January 2006 (Odyssey orbits ~816 to ~18,000)

Bands	1x	2x	4x	Total
12345	736	2560	357	3653
1234	605	1612	188	2405
1235	0	0	0	0
1245	7	5	4	16
1345	2	2	0	4
2345	0	0	0	0
123	63	11	0	74
124	17	262	717	996
125	0	0	0	0
134	5	1	0	6
135	0	1	0	1
145	0	0	2	2
234	13	0	0	13
235	0	0	0	0
245	0	0	0	0
345	0	0	0	0
12	1	1	0	2
13	116	30	245	391
14	25	399	272	696
15	1	1	1	3
23	0	0	0	0
24	1	0	0	1
25	0	0	0	0
34	0	0	0	0
35	0	0	0	0
45	7	6	8	21
1	14	1	1	16
2	13	1	0	14
3	36463	13821	308	50592
4	13	2	1	16
5	13	0	3	16
TOTALS	38114	18717	2107	58938

Observations. Table 1 provides a summary of the number and type of VIS images acquired as of early 2006. In this table, "Bands" refers to the combination of VIS filters used for a particular imaging sequence. For example, "123" means Bands 1, 2, and 3 were acquired in a sequence. 1x, 2x, and 4x refer to 18, 36, and 72 m/pixel imaging modes, respectively. About 86% of VIS images are single-band images, and most of these are acquired in Band 3 (654 nm) as part of the VIS high-resolution global morphologic mapping campaign which has covered approximately 35% of the planet to date. The remaining ~14% of the images are multi-band. Most of these have been acquired in all three spatial sampling modes using filter combinations 12345 or 1234. The latter combination has become the default "all VIS bands" combination since it was discovered that instrumental and calibration problems prevent the effective use of VIS Band 5 (860 nm) [2].

Analysis. We have map-projected and examined 7923 radiance-calibrated [2] VIS color sequences up to about orbit 16,666 (Sep. 2005) [3]. Our initial assessment of the images was based on visual inspection of false color composites for each mapped and co-registered image. The false color composites were generated by scaling each of Bands 123 (or the closest combination possible) to plus or minus 1 standard deviation from its mean and merging these into a 24-bit color RGB TIFF file. Many of the images exhibit spectacular morphologic detail [*e.g.*, 4-7], and most of them exhibit some sort of significant albedo or brightness contrasts (for example, along shadows related to the late afternoon viewing conditions or at the boundaries of polar ice deposits). However, in this initial assessment we sought to identify just that subset of the VIS multispectral images which exhibited the most "interesting" (to us) spectral variability. That is, color variability that (a) appears correlated with morphologic and/or topographic features in the scene, (b) is small-scale, and (c) is not related to obvious instrumental or calibration artifacts. Constraint (a) rules out a large number of images in which variations in dust deposits with no obvious relationship to the underlying geology (other than it providing occasional obstacles) can be seen, and constraint (b) was imposed in order to try to exploit the fact that VIS is the first instrument to observe Mars from orbit in color at sub-100 meter scales.

Restricting the analysis to that definition of "interesting" yielded a surprisingly small number of images–only 633 of the 7923 multispectral sequences (~8%) were flagged for further study. These images were then divided into different geologic categories for more detailed analysis. The categories were: general albedo contrasts, atmospheric features, blue crater deposits, canyonlands, channels & valleys, craters, dunes, dust devil tracks, etched terrain, layered materials, mountains, other blue deposits, polar layers, slope streaks, and wind streaks.

Examples. In this presentation we will show example images and spectra from each of these categories and hypothesize about the origin of the observed color variations. One example is shown in Figure 1. Another relevant example is found in [8].

Implications. Our initial analysis of the VIS multispectral data set appears to indicate that compositionally and/or mineralogically meaningful (beyond "more or less dusty") color variations at visible wavelengths on Mars at 100 meter scales are rare and subtle. *Brightness* variations are common, as are albedo contrasts, but most of the time in the parts of the planet sampled by VIS so far, these variations are not correlated in interesting ways with geologic or morphologic features. Interesting and compositionally-meaningful visible wavelength color variations have been identified at lander and rover (meter to centimeter) scales on Mars [*e.g.*, 9-11], and so the scarcity of these kinds of color variations in the VIS data may reflect a spatial resolution limitation. Or this may just be a manifestation of the spectrally-muting effects of mobile surface and atmospheric dust on the detectability of spectral contrast in the visible, an effect noticed also at rover imaging scales in Gusev crater [12]. Alternately, this observation may reflect sensitivity limitation of the VIS camera itself, which has been found to be subject to a number of calibration challenges [2].

Ultimately, one implication for future multispectral imaging and spectroscopy instruments operating at Mars is that observed geologic or albedo variability is not a guarantee of detectable and compositionally-meaningful spectral variability, even at high spatial resolution. Care should be taken to use all available remote sensing data sets as guides to identify the most promising small-scale regions to explore with future heavily data volume constrained instruments like HiRISE or CRISM.

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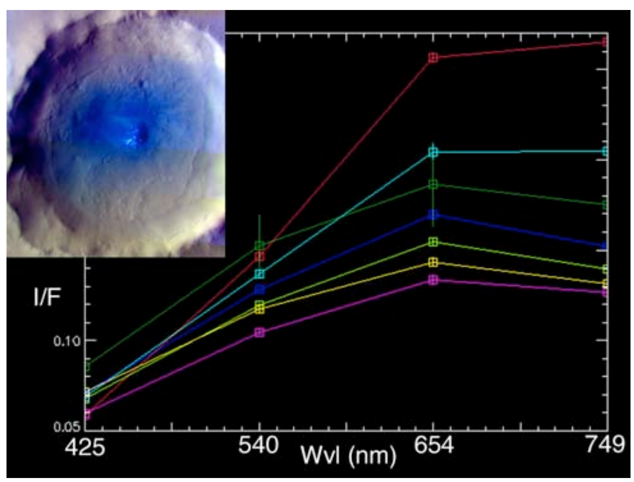

Figure 1. (Inset) portion of VIS image V04893003 (2003-01-21), false color band 123 composite showing anomalous "blue" and "white" interior crater deposits near 51°N, 14°E. Four-band VIS spectra of these deposits are likely related to variations in ferric and ferrous minerals.