PROCESSING MARS GLOBAL SURVEYOR'S (MGS) MARS ORBITER CAMERA WIDE-ANGLE (MOC-WA) IMAGES, AND MARS RECONNAISSANCE ORBITER (MRO) MARS COLOR IMAGER (MARCI) IMAGES.

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Introduction: Exploration of Solar System bodies is most often limited to single moments in time, viewing bodies as a flyby target with most resolved, detailed science imaging taking place during just a few-hours period. In recent decades, Mars joined the ranks of a very few bodies with long-term (multi-year), practically constant imaging of its surface and atmosphere from spacecraft. While the high-pixel-scale imagers tend to be most promoted, the very nature of their high spatial resolution means that they cannot provide nearly continuous monitoring of the whole planet's surface.

Two often overlooked instruments are *Mars Global Surveyor*'s (*MGS*'s) MOC Wide-Angle (MOC-WA) [1] and *Mars Reconnaissance Orbiter*'s (*MRO*'s) Mars Color Imager (MARCI) [2,3]. MOC-WA provided daily color imaging of Mars' surface from 1999 through 2006, across nearly five Mars Years, while MARCI has provided daily color imaging of Mars' surface since 2006, across eight Mars Years and counting. The two missions overlapped just enough to provide three terrestrial weeks of simultaneous coverage.

While many research papers have been published that use these data, in my opinion the data are generally overlooked by the Mars science community, especially the Mars surface science community, for their most common use is in studying atmospheric phenomena (clouds and dust). However, MOC-WA offers ≈6.5 km/pix scale in both orange and violet light, while MARCI offers up to ≈0.6 km/pix scale in infrared, red, orange, green, and violet, plus ≈4.9 km/pix scale in long and short UV (~320 and ~260 nm). With a full time series spanning 22 Earth years and more than 13 Mars Years, this is an unprecedented combined dataset, and yet it is relatively untapped.

Over the past few years, I have worked to process the MOC-WA data and develop tools to process the MARCI data, relying on industry-standard software, but branching out into some possibly *ad hoc* methods, though ones that are still rooted in basic image reduction and processing theory. The MOC-WA manuscript describing the time series is under revision for *JGR-Planets*, while the MARCI manuscript describing the workflow to process those data is under consideration by *Earth & Space Science*, as of January 2022.

Several images demonstrating these datasets are displayed on the second page of this abstract, but they do not have a specific call-out in the text.

MOC-WA: MOC-WA was a line-scan camera with both an orange ("red") and violet ("blue") component. When operated in a certain spatial-summing mode, they produced images 386 pixels wide which, at *MGS*'s altitude, provided spatial scales near 6.5 km/pix.

Processing-wise, the most difficult aspect of using these camera data is the signal-to-noise, which is very low compared with modern imagers, especially for the blue channel (~20:1 or less). Combined with Mars' phase function and the need for better instrument flat-fields, I have found that averaging over fairly long periods of time is needed to create mosaics that appear reasonably consistent across the entire body and with good signal-to-noise. Specifically, I use $\Delta L_s = 10°$ intervals, corresponding to ≈19 Earth days.

MARCI: The MARCI camera is built differently from MOC-WA, using a single detector with several color filters bonded to it. The detector has 1024 usable pixels across it, and each color has 16 pixels along-track, meaning that the camera operates as a push-frame, taking 16-pixel-high framelets in alternating colors that then repeats over slightly similar real estate as the craft orbits Mars, building a full image in seven colors over the course of nearly one hour. With *MRO*'s orbit, the native scale is near 0.6 km/pix, but this is varied by different spatial-summing modes: UV is always operated in an 8× mode, producing images 128 pix wide with framelets 2 pix tall; and the VIS is operated in either 1× or 2× mode, each roughly half the mission. While MARCI is seven-color, it is sometimes operated in reduced-color mode, the most common reduced mode being UV, violet, green, and orange.

MARCI data processing has more issues than MOC-WA, not the least of which is file sizes: While a full MARCI image can be downloaded from PDS and is ≈110 MB, by the time it is processed and map-projected, it balloons to ~2 GB. For one Earth month with ~300 images, this can become unwieldy.

Another impediment to easy MARCI processing is the extreme geometry: *MRO* is closer to Mars than *MGS*, so to maintain daily coverage, MARCI has an extremely fisheye lens (180° field-of-view), providing significant distortions off-nadir and significantly slowing processing time unless images are heavily cropped.

Additionally, Mars' phase function is a more significant issue than for MOC-WA due to: (1) the more significant variation in viewing geometry in a single image, and (2) the increased pixel scale and signal-to-noise making mismatches between images more glaring. Without accurate photometric modeling, artifacts from the phase function become very obvious.

Despite these issues, the workflow I developed is capable of producing full-resolution, high-quality MARCI images, as shown on the next page.

References: [1] Malin et al. (1991). doi: 10.1002/ima.1850030205. [2] Malin et al. (2021). doi:10.1029/1999JE001145. [3] Bell et al. (2018). doi:10.1029/2008JE003315.

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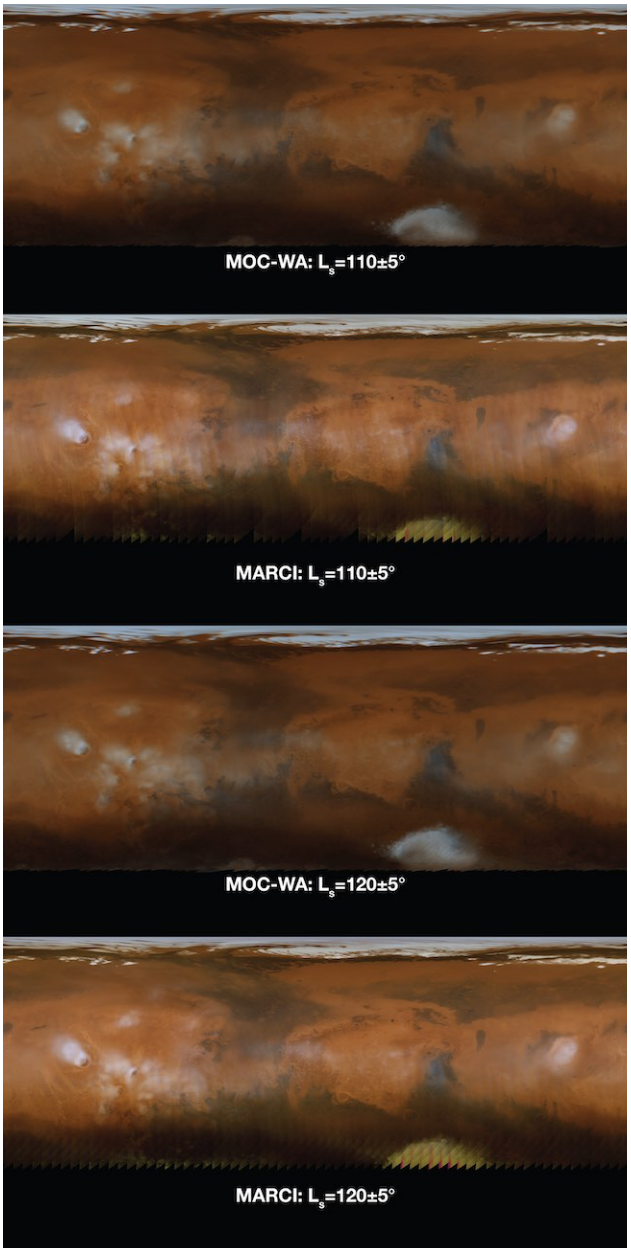

Figure: Global views of Mars in 2006 showing the same time periods imaged by both MOC-WA and MARC, where a synthetic green channel has been created for the MOC-WA data.

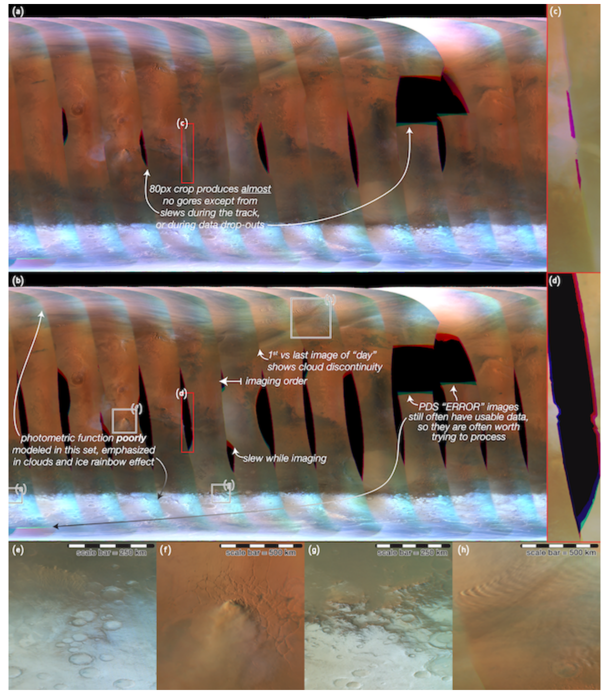

Figure: Global mosaic of one day using MARCI data showing *numerous* different phenomena, including high-resolution versions of several areas in the bottom row. Panels (c) and (d) show seams between images using different amounts of crop in an effort to reduce the time required for processing. The dominant characteristic of the global views (panels (a) and (b)) show the issue of applying a single phase function correction globally, given that the typical Martian regolith has a different response than ice.

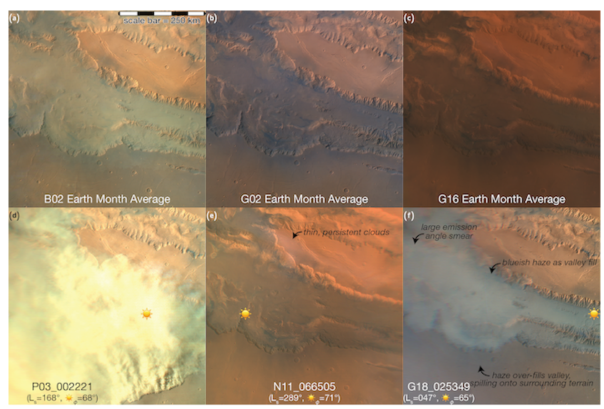

Figure: 10°×10° region of Valles Marineris at high-resolution with the *same* color processing applied to every panel, showing significant color balance changes, brightness changes, and weather visible from MARCI.