8-1-2022

Mastcam-Z multispectral database from the Perseverance rover's traverse in the Jezero crater floor, Mars (sols 0-380)

Melissa S. Rice
Western Washington University, melissa.rice@wwu.edu

Jeffrey R. Johnson
Johns Hopkins University Applied Physics Laboratory

Chase C. Million
Million Concepts

Michael St. Clair
Million Concepts

Briony N. Horgan
Purdue University

See next page for additional authors

Authors

Melissa S. Rice, Jeffrey R. Johnson, Chase C. Million, Michael St. Clair, Briony N. Horgan, Alicia Vaughan, Jorge I. Núñez, Bradley Garczynski, Sabrina Curtis, Kjartan B. Kinch, Marco Merusi, Alex Hayes, James F. Bell, Louise Duflot, Kristiana Lapo, Acacia A. Evans, Alivia Eng, Edward Cloutis, Adrian Brown, and Andrew A. Annex

Mastcam-Z multispectral database from the Perseverance rover's traverse in the Jezero crater floor, Mars (sols 0-380)

Data Processing

The Mastcam-Z instrument on NASA's Perseverance rover is a pair of multispectral, stereoscopic zoom-lens cameras that provide broadband red/green/blue (RGB), narrowband visible to near-infrared color (VNIR, 440-1020 nm wavelength range) (Bell et al., 2021). We used near-simultaneous observations of the Mastcam-Z calibration targets (Kinch et al., 2020) with pre-flight calibration coefficients (Hayes et al., 2021) to calibrate Mastcam-Z surface observations to radiance factor (I/F, or "IOF," where I is equal to the measured scene radiance and πF is the solar irradiance received at the surface at the time of the observation).

We compiled a database of Mastcam-Z spectra from Perseverance's exploration of the Jezero crater floor in the first 380 sols of its mission. This database includes a total of 318 observations (eight observations from this period were excluded because of extensive shadowing, failed image execution, known calibration issues, and/or incomplete downlink). For multispectral mosaics, we treated each pointing as a unique observation. While each pointing of a mosaic shares a common sequence identifier number (seqID), individual pointings can be separated using their remote sensing mast (RSM) position counters.

For each Mastcam-Z multispectral observation, we characterized the spectral variability in the scene through a visual inspection of natural color red, green, blue (RGB) images, enhanced color images derived by stretching narrowband images, and decorrelation stretch (DCS) products (Gillespie et al., 1986). The stretched image products were produced programmatically by the Automated Spectral Data Functions ('asdf') workflow (St. Clair et al., 2022). We identified end members within each scene as groupings of pixels that exhibited distinct colors in the false color and DCS products and also represented geologically-distinct surfaces.

We extracted a representative spectrum of each end member by manually selecting pixels from regions of interest (ROIs) in the right and left Mastcam-Z images separately, taking care to select the same regions of the surface. We utilized the "best practices" described by Rice et al. (2022) for ROI selection in Mastcam images. In the resulting ROI spectra, we represent error values in IOF as the standard deviation among the selected pixels; this is a measure of the homogeneity of the pixel values within the ROI, and is generally much larger than the instrumental error (Hayes et al., 2021).

We compiled each endmember spectrum with extensive metadata. Observation-level metadata were taken directly from the Mastcam-Z images' Planetary Data System version 4 (PDS4) headers, and geographic information was taken from localization data provided for each rover position in the PDS. Each spectrum was manually assigned a number of ROI-specific fields to categorize their rock and soil properties.

File Formats

CSV, FITS, PNG

Dataset Description: ROI_files.zip

Regions of Interest (ROIs) from which all spectra in the database (Mastcam-Z_multispectral_database.csv) were extracted. All files are compressed FITS files. Filenames are given as "roi_solXXXX_zcamYYYY_rsmZZZ-N.fits.gz," where XXXX is the sol number, YYYY is the sequence identifier number, ZZZ is the remote sensing mast position index, and N is the analysis name (appended when more than one ROI file exists for a single observation).

Dataset Description: ROI_context_images.zip

Context images for Regions of Interest (ROIs) for each Mastcam-Z multispectral observation in the database (Mastcam-Z_multispectral_database.csv). All images are PNG files. ROIs are shown as polygons overlain on natural color red, green and blue (RGB) images from Mastcam-Z L0 and R0 filters. The ROI color in each image corresponds to a unique spectrum in the database. Filenames are given as "context_image_C_solXXXX_zcamYYYY_rsmZZZ-N.png," where C is the camera (left or right), XXXX is the sol number, YYYY is the sequence identifier number, ZZZ is the remote sensing mast position index, and N is the analysis name (appended when more than one ROI file exists for a single observation).

Dataset Description: Composite_images.zip

Enhanced color and decorrelation stretch composite images for all observations in the database (Mastcam-Z_multispectral_database.csv). All images are PNG files. The composites are made with the L2 (754 nm), L5 (528 nm) and L6 (442 nm) filters. Filenames are given as "COMP_L2_L5_L6_solXXXX_zcamYYYY_rsmZZZ.png," where COMP is the composite type ("dcs" or "enhanced_color"), XXXX is the sol number, YYYY is the sequence identifier number, ZZZ is the remote sensing mast position index.

Dataset Description: Mastcam-Z_multispectral_database.csv

NAME	Target name associated with the Mastcam-Z sequence, appended with "_XofY" for mosaic observations (where X is the pointing number and Y is the total number of pointings in the mosaic)
SOL	Martian day of Perseverance's mission
LTST	Local True Solar Time when the sequence began on Mars, in units of seconds past midnight
SEQ_ID	Mastcam-Z sequence identifier number
ROVER_ELEVATION	Elevation of the rover in meters
INCIDENCE_ANGLE	Incidence angle for the center of the image when the sequence began on Mars, calculated from the Solar Elevation field in the Mastcam-Z image header
EMISSION_ANGLE	Emission angle for the center of the image when the sequence began on Mars, calculated from the Instrument Elevation field in the Mastcam-Z image header
PHASE_ANGLE	Phase angle for the center of the image when the sequence began on Mars, calculated from the Solar Elevation, Instrument

	Elevation, Instrument Azimuth and Solar Azimuth fields in the Mastcam-Z image header
LAT	Rover latitude
LON	Rover longitude
ODOMETRY	Rover distance traveled in meters
SCLK	Spacecraft clock time
ROI_COLOR	Color assigned to the Region of Interest from which pixels were averaged to extract the Mastcam spectrum; colors correspond to those shown in the context images
FEATURE	Type of surface feature (rock, soil, pebble or hardware)
FORMATION	Stratigraphic position (for rock targets only)
MEMBER	Stratigraphic position (for rock targets only)
FLOAT	Designation of rocks as “in-place,” “float” (not attached to outcrop) or “unclear”
ZOOM	Zoom position
RSM	Remote sensing mast position index
COMPRESSION	Image compression type
ROCK_SURFACE	Rock surface type (thick dust, bright natural surface, dark natural surface, abraded surface, coating (not dust), or tailings)
GRAIN_SIZE	Qualitative assessment of soil grain size as fine (grains not resolvable), coarse (grains resolvable) or mixed
SOIL_LOCATION	Soil surface type (undisturbed, wheel track, disturbed surface (not wheel track), bedform crest/slope, on rock, or on hardware)
DISTANCE	Qualitative distance assessment (nearfield, midfield or farfield)
ANALYSIS_NAME	Specifier appended to ROI filenames when more than one ROI file exists for a single observation
MIN_COUNTS	Minimum number of pixels included in the ROI for any filter
UNITS	Reflectance units used; IOF is the “radiance factor,” which can be converted to “reflectance factor” (*R**) by dividing by the cosine of the solar incidence angle
L6	Reflectance at 442 nm
L0B	Reflectance at 480 nm
R0B	Reflectance at 480 nm
L5	Reflectance at 528 nm
L0G	Reflectance at 554 nm
R0G	Reflectance at 554 nm
L4	Reflectance at 605 nm
L0R	Reflectance at 630 nm
R0R	Reflectance at 630 nm
L3	Reflectance at 677 nm
L2	Reflectance at 754 nm
L1	Reflectance at 800 nm
R1	Reflectance at 800 nm
R2	Reflectance at 866 nm
R3	Reflectance at 910 nm
R4	Reflectance at 939 nm
R5	Reflectance at 978 nm

R6	Reflectance at 1022 nm
L6_ERR	Standard deviation at 442 nm
L0B_ERR	Standard deviation at 480 nm
R0B_ERR	Standard deviation at 480 nm
L5_ERR	Standard deviation at 528 nm
L0G_ERR	Standard deviation at 554 nm
R0G_ERR	Standard deviation at 554 nm
L4_ERR	Standard deviation at 605 nm
L0R_ERR	Standard deviation at 630 nm
R0R_ERR	Standard deviation at 630 nm
L3_ERR	Standard deviation at 677 nm
L2_ERR	Standard deviation at 754 nm
L1_ERR	Standard deviation at 800 nm
R1_ERR	Standard deviation at 800 nm
R2_ERR	Standard deviation at 866 nm
R3_ERR	Standard deviation at 910 nm
R4_ERR	Standard deviation at 939 nm
R5_ERR	Standard deviation at 978 nm
R6_ERR	Standard deviation at 1022 nm
FILTER_AVG	Average reflectance of all filters
ERR_AVG	Average of the standard deviations for all filters
REL_ERR_AVG	Average of the standard deviations for all filters relative to their reflectance values

References

Bell, J.F., III, Maki, J. N., Mehall, G. L., Revine, M. A., Caplinger, M. A., Bailey, Z. J. et al. (2021). The Mars 2020 Perseverance Rover Mast Camera Zoom (Mastcam-Z) Multispectral, Stereoscopic Imaging Investigation. *Space Science Reviews, 217*(24). https://doi.org/10.1007/s11214-020-00755-x.

Gillespie, A., Kahle, A., & Walker, R. (1986). Color enhancement of highly correlated images. I. Decorrelation and HSI contrast stretches. *Remote Sensing of Environment, 20*(3), 209–235. https://doi.org/10.1016/0034-4257(86)90044-1.

Hayes, A. G., Corlies, P., Tate, C., Barrington, M., Bell, J. F. III, Maki, J. N. et al. (2021). Pre-Flight Calibration of the Mars 2020 Rover Mastcam Zoom (Mastcam-Z) Multispectral, Stereoscopic Imager. *Space Science Reviews, 217*, 29. https://doi.org/10.1007/s11214-021-00795-x.

Kinch, K. M., Madesen, M. B., Bell, J. F. III, Maki, J. N., Bailey, Z., Hayes, A. G. et al. (2020). Radiometric calibration targets for the Mastcam-Z camera on the Mars 2020 rover mission. *Space Sciences Reviews, 216*, 141. https://doi.org/10.1007/s11214-020-00774-8.

Rice, M. S., Seeger, C., Bell, J., Calef, F., St. Clair, M., Eng, A., et al. (2022). Spectral diversity of rocks and soils in Mastcam observations along the Curiosity rover's traverse in Gale crater, Mars. Journal of Geophysical Research: Planets, 127, e2021JE007134. https://doi.org/10.1029/2021JE007134.

St. Clair, M., Million, C., Rice, M. S. (2022). marslab software suite. https://zenodo.org/badge/latestdoi/498892781.