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More Than Two Mars Years of Atmospheric Dust Characterization from Jezero Crater using Mars 2020 Mastcam-Z Direct Imaging of the Sun, Sky, and Calibration Targets

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NASA's Mars 2020 Perseverance rover, which landed in Jezero Crater in February 2021, represents a major advance in the exploration of Mars' ancient habitability and present-day environment. The rover's Mastcam-Z instrument – a multispectral, stereoscopic, zoomable camera system – provides high-resolution imaging for both geologic and atmospheric science [1]. Mastcam-Z enables broadband red/green/blue and narrowband visible-to-shortwave infrared imaging, with filters appropriate for direct solar and sky observations [2-4].

A central science objective of the Mastcam-Z investigation is to characterize the radiative properties of atmospheric dust, a key driver of Martian climate and weather. Direct imaging of the Sun and sky at multiple wavelengths and well-selected temporal sampling allows for robust measurement of atmospheric column-integrated optical depth (a.k.a., τ, the coefficient representing extinction that goes as $e^{-\tau}$), providing constraints on dust column abundance and its temporal and spatial variability [*e.g.,* 5]. These measurements are crucial for understanding dust radiative effects, variability in solar energy reaching the surface, and the dynamics of dust lifting and transport [*e.g.,* 6].

The observation strategy employs a systematic, high-cadence sampling of solar disk, sky, and calibration target imaging, often multiple times per sol. This approach captures diurnal and seasonal changes in both atmospheric and rover deck dust loading and basic particle properties such as particle size [*e.g.,* 7,8]. Observations acquired along the rover's >37 km traverse across Jezero Crater so far also provide the potential opportunity to characterize local vs. regional dust characteristics. The resulting surface and atmospheric dust opacity record is the most extensive and highest temporal resolution ever obtained from the Martian surface, revealing significant sol-to-sol and seasonal variability in atmospheric and surface dust over more than 2.3 Mars years so far [*e.g.,* 3,4].

The Mastcam-Z record of atmospheric observations and the associated aerosol retrieval products are directly connected to understanding current climate processes, informing models of dust storm initiation, and assessing environmental conditions for future robotic and human exploration. In addition, these Mastcam-Z measurements offer a type of "ground truth" to validate dynamical models of the Martian atmosphere. This validation is a fundamental step in allow such tools be applied to earlier periods in Martian history.

While the current record captures multiple Martian years, future observations will allow for the expansion of the temporal record to investigate repeatability and interannual variability. Extended observations will also include targeting additional seasons (*e.g.*, aphelion cloud belt), dust events, and mesoscale interactions with surface features and local weather phenomena. Thus, the Mastcam-Z record of atmospheric observations further advances our understanding of dust's role in shaping the Martian environment across geological eras.

References:

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