Paradigm shifts towards understanding the full story of Mars, a possible future.
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The context: We envision that it is 2050 and a new phase of Mars exploration and Planetary Science investigations has opened – similar to the way in which our understanding of the Earth changed between the 1960s and 2017. As with the realization of Plate Tectonics or climate cycles such as El Nino, enough data has been collected for Mars to be seen through a much more holistic lens. Individual datasets and models now fit together within a larger "story," one that encompasses the variety of compositions and structures found around Mars and finds them all to be generally consistent within a common set of interacting processes and global history.

This has had a profound impact in how we understand Mars as:

- an individual planet with complex processes, systems that transport materials over a range of scales, and an evolution history;
- a place where we can consider analog or completely-different-end-member comparisons with regards to climate, environment, and life within our Earth systems;
- and a well-studied member of the solar system, where the planetary bodies continually surprise us with their variety and activity yet all formed within the same "story" of solar-system environment conditions/states and processes.

Here, we explore a possible path for achieving this new understanding.

Early exploration: As with most new exploration programs, early Mars investigations involved large-scale surveys. Efforts were focused on just seeing what was there, and some basic interpretations. For example, at first, geologic climate variations were recognized within coarse-resolution images, and were hypothesized to occur on Epoch timescales and within very-large scale terrains – the Noachian appeared to have been very wet (and possibly even Earth-like in environment, leading to questions about habitability), there was a decrease in wetness through the Hesperian, and then into the dry Amazonian.

As the "survey" data collection yielded variations within those Epochs/large-scale terrains, however, this simple model was shown to not be sufficient. Observations yielded signs that the early Mars climate may have been cold and icy with only transient periods of warm and wet. Obliquity cycles were also discovered, providing a reason for Mars' regional climates to vary on million-year timescales (with e.g., the extent of "polar" ice), not just over billion-year timescales; and explaining some of the geologic records that implied recent variation and even cycling.

Furthermore, higher-resolution orbital data was coupled with in situ measurements by rovers, allowing for piecemeal, deep investigations of specific locations. As more data was collected and correlated, the investigations of Mars moved away from the large-scale sweeping categorizations and interpretations into exploration of the nuances. High priority science questions were phrased within a recognition that variation and evolution happens, rather than reflecting assumption of an overly simple story.

Since 2017: Two types of observations have been instrumental in enabling Mars science investigations to move into yet more integrated analyses:

(1) Systemic, long-term coverage with ever improving spatial resolution across all wavelengths has allowed us to monitor and characterize the changes occurring over the modern-day planet, and

(2) Observations from networks (both landed and orbital) have allowed for concurrent observation of a range of locations and over all times of day.

These two types of observations allow us to see the full story of what is happening and what has happened on Mars. Within that context, we are better able to spatially and temporally correlate different datasets at a range of scales. We are more able to see how martian materials are transported and how environmental conditions shift, generating the variation in structure and composition seen at all scales within the atmosphere, surface, and sub-surface. We are also able to decouple local-scale perturbations (in space and time) from seasonal cycles and interannual changes, which allows for accurate refinement of state-of-the-art modeling tools, developed for earth and scaled/modified for use on Mars. For example, in 2050, these now provide routine weather forecasting which enables improved planning for exploration by humans and robots.

The development of satellite networks also allowed for the use of numerous small-satellites and spacecraft in the investigations, as now a "ride" and telecommunications could be covered by the primary mission. This technological shift in capability thus enabled an increase in the amount of data collected and investigations that could be addressed, that outpaced the number of primary missions flown. Additionally, the use of numerous, smaller payloads added to the overall access to Mars, enabling a much wider survey and collection of data, and thus feeding back into the studies that rely upon concurrent measurements from a range of locales. (Furthermore, this and a range of citizen science efforts have allowed a larger population to engage with and contribute towards Mars exploration.)

Improved *in situ measurements*, including drilling within both rock and polar ice samples, have allowed for critical and unprecedented groundtruth checks for orbital datasets. Additionally, the timing of important environmental changes has been determined by in situ dating of both icy and rocky materials. Samples returned to Earth laboratories have also allowed for state-of-the-art analyses for composition and dating measurements. In situ analyses also took a leap forward with extended stays by humans on the martian surface, aided by their operation of remote robots.

All of these advancements – *in measurement coverage, resolution and type; in technology and access; and in model/context development* -- have allowed us to greatly advance and quicken how we test hypotheses about how the components of the planet's system interact with each other. These have enabled a much better of idea of how to fit both old and new datasets together and extrapolate between and from them. In particular, major advancements have occurred in our understanding of the polar atmosphere and ice systems (which has led to improved interpretation of landforms and identification of resources for human exploration – such as accessible lower-latitude ice reservoirs), interior science (which was a neglected "boundary" within our study of the full martian system), and atmosphere cycles and transport (which also was a neglected "boundary," and which has been vital for enabling weather forecasting). These all have also been important for understanding how Mars has changed through its history – over epochs and over shorter time periods. For example, these advancements in measurements and models have improved our interpretations of the climate record within the martian polar layered deposits (as global atmospheric processes strongly influence how much dust and ice is available for deposition to form the layers, and the polar atmosphere and surface conditions and processes have influence over how the dust and ice is deposited and if that deposit is retained within the record), with historic changes dated and traced through the rest of Mars' record.

Frequent and strategic access to the planet has enabled our knowledge of Mars to develop to a maturity beyond that achieved elsewhere in the solar system (other than at our home planet). Additionally, the studies that have made this progress possible have come from a *broad and diverse community of researchers*. From this: our understanding of the larger "story" of Mars has greatly advanced our knowledge about how environments and climates on a planetary body can change and be represented within geologic records; models of physical processes active on the Earth, Mars, and other rocky bodies; and the formation and evolution of the terrestrial planets.