# MARS WEATHER AND CLIMATE: AN ORBITAL CONSTELLATION FOR ATMOSPHERIC PROFILING AND SURFACE THERMOPHYSICS

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**Goals:** Over the last decade considerable progress has been made in understanding the structure of the martian atmosphere and surface-atmosphere interactions. Current work focuses on identifying dynamical processes and radiative effects that are responsible for shaping the atmosphere of Mars. Progress in the area of weather and climate on Mars will depend on achieving two major science goals:

1. **Build a long-term record of the current martian climate to characterize the Amazonian**
2. **Globally characterize martian weather**

Goal 1 addresses the question of whether there are significant changes in the martian climate on 10 to 1000 year timescales [1]. With atmospheric and surface observations by the Thermal Emission Spectrometer (TES) from MY 24-26 and by the Mars Climate Sounder (MCS) from MY 28 to the present (MY 34) [2] we are about to enter an era where time series of orbital measurements allow extrapolation to Amazonian time scales. Only long-term climatologies allow the characterization of interannual variabilities and systematics [3]. Global dust events have major impacts on the surface and atmosphere in some years but the hiatus in their occurrence since MY 28 emphasizes the need for long-term observaions. Trends, e.g. in dust storm occurrences and dust fluxes, will only be uncovered by long-term stable and consistent measurements.

Goal 2 addresses improving understanding of short-term processes that form martian weather. One issue that limits progress in this area is the lack of coverage of observations at multiple local times, such that many short-term processes are not well characterized. These include forcing of semi-diurnal tides and higher order modes, which reveal strong radiative influences of water ice clouds and affect the general atmospheric circulation [4]. Furthermore, the inhomogeneous vertical distribution of atmospheric dust suggests that convective activity triggered by solar heating of dust may play a crucial role in dust transport and possibly the formation and growth of global dust events [5]. In addition, diurnal $H_2O$ and $CO_2$ frosts may have a significant impact on the regolith structure that is not well described [6]. Characterizing such processes globally at timescales of less than a sol would also provide an improved basis for assimilating data into General Circulation Models, which has proven challenging [7]. Assimilating near real-time atmospheric and surface data could pave the way towards forecasting martian weather in support of landing, aerocapture and surface operations of future manned and robotic missions.

**Concept:** The proposed goals require global profile measurements of atmospheric temperature, dust, water ice and water vapor, as well as surface temperature, at multiple local times. We suggest a constellation of SmallSats or CubeSats in Mars orbit to perform these measurements. The satellites would be deployed in low-altitude orbits of moderate to high inclination around Mars. A constant node spacing of 45° between orbits would ensure that atmospheric and surface observations over the same areas would be performed in regular local time intervals of 3 hours.

Measurements would be based on passive infrared radiometry in limb and nadir geometry as demonstrated by MCS [8] operating on MRO since 2006. Profiles of temperature, dust and water ice with 5 km vertical resolution have been retrieved from these measurements [9] together with atmospherically corrected surface temperature [6]. Future measurements with the same approach and technology would ensure comparability with the existing 6 Mars Year climatology [2].

The mission concept would advance the understanding of how physical processes in our solar system operate, interact and evolve as outlined in the 2014 NASA Science Plan. The MEPAG Goals document explicitly solicits the measurement of atmospheric parameters at multiple local times.

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**References:** [1] Visions and Voyages (2012) *NRC Press*. [2] Schofield, J. T. et al. (2018) *COSPAR*. [3] Kass, D. et al. (2016) *GRL 43*, 6111-6118. [4] Kleinböhl, A. et al. (2013) *GRL 40*, 1952-1959. [5] Spiga, A., et al. (2013) *JGR 118*, 746-767. [6] Piqueux, S., et al. (2016) *JGR 121*, 1174–1189. [7] Navarro, T., et al. (2017) *ESS 4*, 690–722. [8] McCleese, D. J. et al., (2007) *JGR 112*, E05S06. [9] Kleinböhl, A. et al. (2009) *JGR 114*, E10006.