ENABLING IN SITU OBSERVATIONS OF ACTIVE SURFACE-ATMOSPHERIC INTERACTIONS ON MARS (AND MAYBE OTHER BODIES). S. Diniega[1] (serina.diniega@jpl.nasa.gov), Brian Jackson[2], Alejandro Soto[3], Don Banfield[4], Christy Swann[5], Edgard G. Rivera-Valentín[6], [1]Jet Propulsion Laboratory, California Institute of Technology, [2]Boise State University, [3]Southwest Research Institute, [4]NASA Ames Research Center, [5]U.S. Naval Research Laboratory, [6]Johns Hopkins University Applied Physics Laboratory.

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A community, aiming to collect observations of active physical processes on other planetary bodies, is growing amongst planetary and terrestrial scientists, instrument developers, and mission engineers. A workshop held in June 2022 (*PlanetInsitu22* [1]) aimed to consolidate definition of the main in situ measurements needed to significantly advance scientific understanding of volatile, wind, sediment, and frost-driven processes that are shaping planetary surfaces; **follow-up workshops** are now being planned in conjunction with the *Brines in the Solar System: Ancient and Future* conference in May, 2023 and the *International Conference on Aeolian Research* in July, 2023. Additionally, the *Planetary Science Journal* invites papers for a **special issue** on "Towards in situ observations of planetary surface-atmosphere interactions." Finally, we are establishing a **website and mailing list** for sharing opportunities and other relevant announcements – see http://planetinsitu.space/ or https://mailman.boulder.swri.edu/mailman/listinfo/planetinsitu to sign up for the list.

The need for planetary in situ observations: Aeolian (wind-driven) sand and dust are known to significantly influence landscape evolution and climate across the solar system and could significantly impact future human exploration (e.g., biohazards, clogged seals, or interrupted operations), but many of the driving forces are not well-understood outside of terrestrial conditions [2-7]. Volatile-driven processes on planetary surfaces have even more open questions and are also strongly connected to geologic and climate activity [4,7-9], and many (e.g., sublimation-dominant seasonal activity) lack clear terrestrial analogues.

To validate and calibrate models describing these physical phenomena, correlated in situ observations of both the surface activity and near-surface/local environment are needed. Such in situ data, providing ground truth for the models, also complements coarser-resolution orbit-based studies of geomorphology, stratigraphy, and composition [4] that connect to the broader systems. Furthermore, understanding how a specific planet's conditions affect the expression of a process guides our understanding of the fundamental (i.e., planet-agnostic) physics at work.

Current state of knowledge and capability for acquiring such observations: To date, Mars is the only planetary body where some in situ measurements of meteorology and volatile/aeolian activity have been acquired. However, on previous Mars missions the relevant instruments were accommodated sub-optimally among other payload elements and thus did not yield the type of comprehensive, integrated, and detailed data needed to robustly test and guide models. Targeted, high-fidelity, and long-duration in situ investigations of surface and atmosphere processes outside of Earth have not yet been accomplished, due in part to technology limitations (discussed below).

Fortunately, recent advances in small lander design (especially to Mars), instruments, and operations designs make low-cost, low-risk, and high-value mission concepts feasible in the next decade [10,11]. Furthermore, many investigations of surface and atmospheric activity work particularly well with small spacecraft designs as the needed payload is small and landing site constraints yield large targets (i.e., the requirement is to land somewhere within a big windy field, rather than next to a specific outcrop). Some investigations would also benefit from numerous in situ measurements sites, with multiple (possibly identical) spacecraft, but may not require that their periods of observation overlap [12].

High-priority in situ science measurements: To optimize science advancement, observations of the environment and activity need to be acquired with high frequency and fidelity, at least when the activity is happening, so as to characterize trends and dynamic range over multiple scales (e.g., capturing diurnal and seasonal wind velocity patterns as well as the timing and magnitude of gusts). Contextual information is also needed so that results from the in situ study can be extrapolated, via a model, to locations where detailed in situ measurements have not been collected. Definition of the types of measurements that could be collected together (and potential instrument suites) has been well-developed through analogous terrestrial studies and community discussions [e.g., 1].

In general, the in situ measurements of interest for characterizing wind- or volatile-driven activity share the following considerations [1]:

- **High frequency measurements during "events"** of interest, and low frequency measurements during other times, so as to characterize the broader trends.
- **Observations are collected within a simple enough site** to match to the model, and generally from a fixed location through a long time period so as to observe and decouple diurnal and seasonal cycles/perturbations. (Ideally, the site would also contain enough complexity to enable extrapolation to more complicated situations. Alternatively, multiples sites could be studied, with varying levels and/or types of complexities.)
- **Sufficient contextual measurements** are needed to properly calibrate the model.
- **Instruments need to be operational within an active environment** (e.g., can collect data during active saltation, and afterwards).

High-priority technology challenges: With some of the small spacecraft mission concepts under development for in situ investigation of meteorological and aeolian activity on Mars, these are some of the often-mentioned challenges, in rough order of priority. They are described in a bit more detail in [10,11].

- **Lower cost access to a planet's surface** with a small (5-10kg) science payload. The SHIELD concept is one idea for Mars [13].
- **Collection of measurements over a vertical profile**, including wind, temperature, volatiles, and other measurements, starting from the surface [7]. Options include a deployable boom with several fixed sensors or a sensor that can move up/down, or a drone/balloon carrying sensors up through a higher range of elevations.
- **An operations scheme that enables sufficient frequency/fidelity observation of the dynamic environment**, including capture of transient peak/anomalous events (e.g., wind speed and direction distribution, including gusts, or dust devil passage), while staying within power and downlink envelopes.
- **Survival and operations through extreme conditions**, especially considering thermal and power needs (e.g., through dust storms or winter).
- **One-time mobility within the landing platform** – although a meteorological investigation benefits from being stationary on the Mars surface, a one-time ability to optimally place/orient sensors within the landing environment could enhance science value of the observations.

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