A MAJOR MISSING COMPONENT – AEOLIAN-FLUVIAL INTERACTION ON ANCIENT MARS. R. S. Bahia[1], E. V. Bohacek[1], L. Braat[1], S. Boazman[1], E. Sefton-Nash[1], C. Orgel[1], C. Wilson[1] and L. Riu[2], [1]European Space Research and Technology Centre (ESTEC), European Space Agency, Noordwijk, The Netherlands (rickbir.bahia@esa.int), [2]European Space Astronomy Centre (ESAC), European Space Agency, Madrid, Spain

Introduction: Martian valley networks (VNs) and paleolakes (ancient lakes) are among the most compelling pieces of evidence for ancient flowing liquid water (fluvial activity) on Mars during the Late Noachian to Early Hesperian periods (3.7-3.5 Ga). The VNs likely formed predominantly as a result of precipitation [e.g., 1-3] and volcanic activity followed by groundwater upwelling or ice-melt on the flanks of volcanoes [e.g., 4-6]. Today, landscape evolution is dominated by wind processes in the equatorial and middle latitudes of the planet, evidenced by abundant active aeolian bedforms [e.g., 7]. Furthermore, exposures of preserved ancient aeolian strata are pervasive across the planet and provide a mechanism to study wind regimes and the climate of Mars' past [8, 9].

Analysis of ancient Martian paleolakes has revealed that the climate during the Late Noachian to Early Hesperian was semi-arid to hyper-arid, similar to terrestrial desert environments [10] where interactions between aeolian and fluvial processes have been observed [e.g., 11]. Aeolian and fluvial processes on Earth show significant interactions. Within terrestrial desert environments, analysis of ~200 locations has revealed that where ephemeral or episodic rivers flow across a dune field the predominant processes alternate between aeolian and fluvial, and that when rivers and dunes are active, they interact with one another [11]. For example, in dryer seasons, when river flows are low or zero, the aeolian process can deposit in the channel, in some cases covering the channel with aeolian features such as dunes. When wetter seasons arrive, flood events can erode part or all the aeolian features in the channel, carrying the sediment in the river, or the river may be dammed or caused to migrate, causing the channel location to be diverted. Such diversions can be major, with channels in the northern Kalahari having cumulative diversions of 10s of km [12].

The morphologies of Martian VNs reveal that fluvial activity was predominantly episodic or ephemeral [13, 14], indicating there were periods of fluvial inactivity. Like terrestrial deserts, whilst Martian rivers were active aeolian and fluvial processes likely interacted with one another. Additionally, during the periods of fluvial inactivity, aeolian processes likely persisted, causing deposits of aeolian material within the river valleys and channels. These deposits would require remobilisation by the rivers once they became reactivated. Evidence of such processes are present within Gale Crater, where the Curiosity Rover has observed fluvially altered aeolian deposits [15].

Considering Mars likely had an arid environment during the period of peak fluvial activity [10], the presence of fossilised Martian dunes [e.g., 8, 9], and observations by the Curiosity rover of fluvially altered aeolian deposits [15], it is apparent that Mars likely experienced simultaneous fluvial and aeolian processes, and periods of fluvial inactivity where aeolian processes persisted. At present, Martian aeolian and fluvial processes have only been studied independently, and their interaction has not been explored.

Here we report the initial study by the Working group on Aeolian-Fluvial Terrain Interactions (WAFTI), based at the European Space Agency, which examines the effects of these processes in synergy under ancient Martian conditions, using a combination of modelling and geomorphological analysis. We hypothesise that these interactions could have implications for a number of Martian phenomena, for example: the prevalence of meandering inverted channel systems [e.g., 16], the distribution of organic material [17, 18], the discordance of Martian valley networks [3], and the sediment size and distribution of Martian rivers.

In this study, we simulate the interactions between migrating dunes and different reaches of an active river channel, under ancient Martian conditions to determine the effects on the channel's morphology and geometry. Input parameters for the simulation were extracted from a combination of literature and analysis of remote sensing data.

Datasets and Methods: To simulate the interactions between fluvial and aeolian processes on Mars, we developed the Martian Aeolian-Fluvial Interactions (MAFI) model. This is a landscape evolution model based on a coupled implementation of the Caesar-Lisflood fluvial model, and Discrete ECogeomorphic Aeolian Landscape model (DECAL) dunes model [19]. The Caesar-Lisflood fluvial model routes water over a Digital Elevation Model (DEM) and calculates erosion and deposition from fluvial and slope processes and changes elevations accordingly [20]. It comprises a surface flow model, fluvial erosion and deposition, and slope processes. The DECAL model [21] is based on the Werner slab model of dunes [22], which simulates dune field development through self-organization. The topography is discretized into slabs on the DEM, and slabs are moved across the space according to a set of simple rules.

We test for potential aeolian fluvial interactions on 10 m per pixel DEMs of simplified fluvial geometry: a straight channel with a rectangular cross section, running perpendicular to dune transport in an area of 2 x 5 km. Channel width measurements were taken from literature remote sensing observation of twenty-three Martian channels [23], and averaged (~380 m). This small sample size is based on the limited observations of Martian channels [23]. Channel depth is not reported (likely due to the limited DEM resolution), however, it is known that channel width (*W*) is proportional to channel depth (*H*) from the following equation [24]: $H = 0.164W^{0.66}$. Using this relationship, we determined a reasonable estimate of channel depth (~ 8 m).

For our first experiment, we vary the slope of the region surrounding the channel to examine if aeolian-fluvial interactions vary in the source, mid and termination reaches of a valley network. To best represent the surface slope of valleys/channels on Mars, we calculate slope values for main valleys (the lengthiest of the network) from Bahia et al., (2022) [3] valley map of Mars. The MGS MOLA DEM was used to extract elevation data (~460 m per pixel horizontal resolution). The valleys were split by length into thirds, representing segments for the source, mid-reaches, and termination. Slope was calculated only for main valleys of > 5km in length in order to capture a representative topographic signal on the comparatively coarse MOLA DEM. Elevation data were extracted at 500 m intervals along the segments. Slope (change in elevation divided by change in length) was then calculated for each 500 m interval and averaged for each segment. These values were then averaged to determine the average slope for source, mid-reaches, and termination segments.

Results: Average slopes calculated for source, mid-reaches, and terminations of 742 main valleys, revealed that, like terrestrial valley networks, slope generally decreases from source to termination. Average slopes (m/m): source = 0.022; mid-reaches = 0.019; and terminations = 0.018. We are currently running the MAFI model – results to be determined.

Future Work: At LPSC we will present the results of our simulations for the interactions between aeolian and fluvial process with topography defined by a simple inclined plane with a central channel and a continuously flowing Martian river. Typically, channels are housed within valleys, which for Mars have been noted to have V and U-shaped cross-sections [24]. Additionally, the topography of Mars is heavily altered by, and defined by, impact craters [e.g., 2, 3], many of which are sediment sinks. Finally, the profiles and immaturity of Martian valleys indicate that they were likely ephemeral/episodic, so flow was unlikely to be continuous. We, therefore, plan to expand our study to simulate the following: (1) simulate continuous flow for a DEM with a V-shaped valley and central channel; (2) simulate continuous flow for a DEM with a U-shaped valley and central channel; (3) simulate continuous flow for a DEM with a V-shaped and central channel with a crater present adjacent to the part of the valley; (4) simulate episodic fluid flow with periods of no fluvial activity, but continued aeolian activity. Understanding these two major surface processes in synergy, will aid in the reconstruction of Mars' ancient paleoenvironments in a way that has not previously been explored.

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