GLOBAL MORPHOMETRIC SURVEY OF MARTIAN DELTAIC DEPOSITS: METHODS AND VALIDATION. David A. Vaz[1,2], G. Di Achille[1], Brian M. Hynek[3-4], William Nelson [3-4], Rebecca M. E. Williams[4], [1]INAF, Istituto Nazionale di Astrofisica, Osservatorio Astronomico d'Abruzzo, Via Mentore Maggini, 64100 Teramo TE, Italy (vaz.david@gmail.com), [2]CITEUC, Centre for Earth and Space Research of the University of Coimbra, Observatório Astronómico da Universidade de Coimbra, Almas de Freire, 3040-004 Coimbra, Portugal. [3]Laboratory for Atmospheric and Space Physics, CU Boulder, CO. [4]Dept. of Geological Sciences, CU Boulder, CO. [5]Planetary Science Institute, Tuscon, AZ.

Introduction: Putative fluvio-lacustrine depositional systems on Mars are among the strongest evidences for a wetter past [1-4] suggesting the existence of long standing bodies of water. However, the diversity of regional settings (fan shaped deposits located in crater basins, troughs, etc.), different feeding valley network morphologies, uncertain age and stratigraphy (simple, complex, lobate or stepped fans) make the overall interpretation of these terminal deposits difficult. In particular, the mode of deposition and the amount of time and water necessary to form the fans, and thus their paleoclimatic and hydrological significance, are still debated.

Using CTX imagery and altimetry we are compiling a global database that integrates the morphometry of the fans and associated valley networks. We are doing a volumetric analysis for each deposit, estimating the amount of sediments eroded and mobilized from the valley networks and deposited on the fans. Here we discuss and validate the applied techniques, using delta topography modeled with SEDFLUX [2, 5]. A comparison with previously published volume estimates and the effect of different DTM spatial resolution are also presented.

Datasets and methodologies: We have identified nearly 50 fans with suitable CTX stereo coverage, most of them located on crater walls. NASA AMES stereo pipeline [6] is being used to produce the DTMs and orthoimages (20 and ~6 m/pixel) that are utilized to map the areal extent and compute the volumes of fans and valleys. Triangulation errors are used to propagate the DTM errors to the output volume estimates. HRSC DTMs (50-100 m/pixel) are also used when CTX stereopairs are not available.

All mapped fans are linked to a valley network. The amount of eroded and transported material is estimated by interpolating the original undissected topography of the valleys. We use QGIS software to map a polygon that mark the valleys extent, and use the elevation on the outer edge of the polygons to interpolate (using a natural neighbor algorithm) the pristine topography. The eroded volume is obtained by Riemann integration after subtracting the present day elevations. The same type of approach was previously used by others [7], although we are also computing volume uncertainties by considering DTM errors.

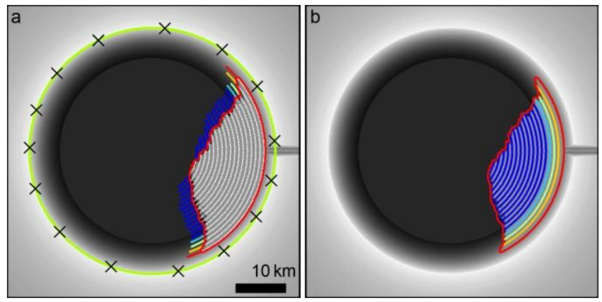

Figure 1 – Example of the technique used to compute the volumes of fan deposits. a) concentric profiles obtained by fitting a circle to the crater rim, the delta outline is used to define an exterior buffer from where elevations are sampled; b) the sampled elevations are then used to interpolate the base of the deposit for each profile.

The volume of the fans is computed by interpolating the base topography from concentric profiles (Fig. 1). The lower elevations (5% percentile) located on the external buffer zones are used to perform a linear interpolation along the profiles (Fig. 1b). Simpler interpolation schemes have been used for the same purpose [7]. However, using the shape of the basins (usually a crater) as a morphological constraint to the profiles' shape produces more accurate results (Fig. 2a). The obtained base surface is used to derive the fan volume by integration, and the triangulation errors are used to propagate uncertainties to the volume estimates.

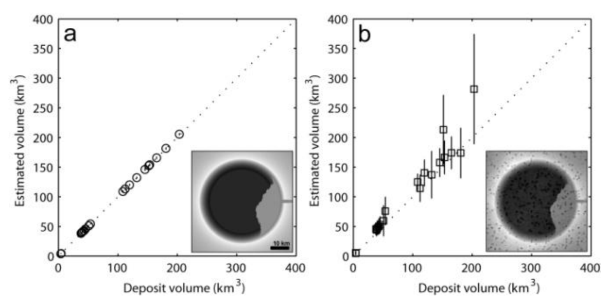

Figure 2 – SEDFLUX modeled delta volumes vs. measured volumes. a) pristine topography, the dotted lines represent perfect accuracy (insets show one of the cases); b) cases where fractal noise and small craters where added to the models output.

Validation of results: With the SEDFLUX models we are able to control the exact amount of sediment that is deposited on a delta. We modeled different sediment discharges and different crater depths in order to obtain various fan volumes and delta morphologies. The fan volume measurements are accurate on all cases producing very narrow uncertainty intervals (Fig. 2a). Adding random fractal noise and small craters to the model output topography results in wider uncertainty bars (Fig. 2a), although the overall accuracy of the estimates is still acceptable. These tests demonstrate the robustness of the adopted techniques.

Previously published fan and valley volume estimates were also analyzed [3,4,7]. There is good agreement in most of the cases (Fig. 3a), although we found very high discrepancies in some cases (e.g. Fig. 4).

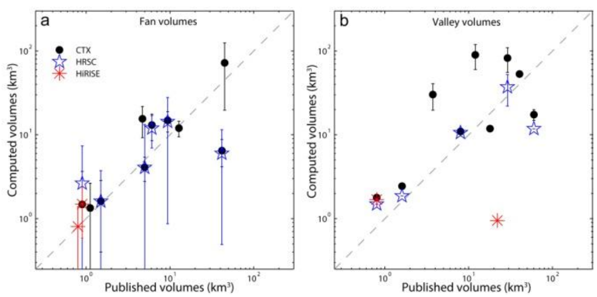

Figure 3 – Comparison of volumes reported by other authors [3,4,7] and computed with CTX, HRSC and HiRISE DTMs following the described techniques for 11 fans. a) fan volumes, note the good agreement between CTX and HRSC estimates; b) valley volumes.

Large disparities are more common in the case of the valleys' volumes (Fig. 3b). In addition, this comparison shows that CTX data consistently produces higher valley volumes when compared with HRSC based estimates. This might be explained by the coarser spatial resolution of the HRSC DTMs. The number of fans/valleys totally covered by HiRISE DTMs is not enough to further evaluate the effect of spatial resolution on the output measurements. However, we note the good agreement between the valley volume estimates obtained from CTX, HRSC and HiRISE for one of the cases (Peace Vallis fan in Gale crater).

Conclusion: The different techniques and datasets currently employed to estimate the volume of valley networks and fan deposits on Mars do not necessarily produce consistent values. This argument justifies the need to perform a global survey using a common and thoroughly tested technique, preferentially with elevation data with constant spatial resolution and quality.

Volume estimates reported in published literature do not report an uncertainty assessment. For the first time, we are computing the uncertainties related with each volume measurement, by taking into account the DTM errors and the predictable local complexity of the underlying topography (in the case of the fans). This is particularly relevant in order to compare at a global scale the different fan-valley systems.

Finally, plotting valley vs. delta volumes shows that the volume ratio is close to one for the majority of the deposits (Fig. 5), suggesting limited dispersion of sediments from the deltas further within the sedimentary basins.

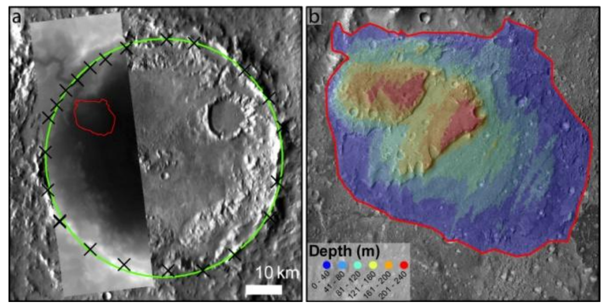

Figure 4 – Stepped fan deposit at the mouth of Tyras Vallis. a) CTX DTM and fitted crater; b) computed sediment thickness; the integration of this dataset produces a volume estimate of 6.8±1.2 km^3, a value that is much lower than previous estimates made with HRSC and MOLA data (41.7 km^3 [4]).

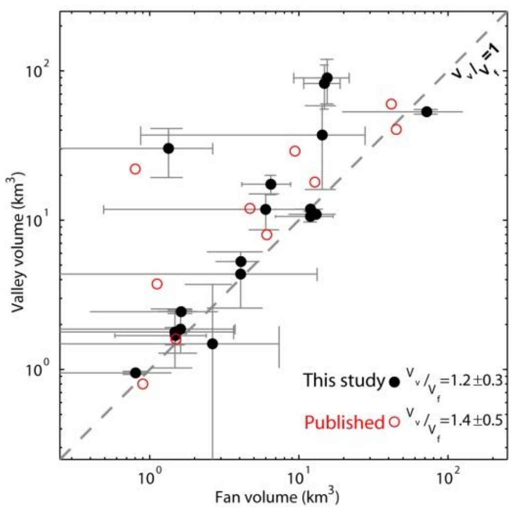

Figure 5 – Relation between valley network (V_v) and fan volumes (V_f). Both datasets present a median ratio close to 1, although some outliers to this trend may be present.

References: [1] Di Achille G. and B. M. Hynek (2010). *Nat. Geosc.*, Vol. 3 (7), 459-463. [2] Hoke M. R. T., et al. (2014). *Icarus*, Vol. 228, 1-12. [3] Kleinhans M. G., et al. (2010). *EPSL*,Vol. 294 (3), 378-392. [4] Di Achille G., et al. (2006). *JGR: Planets*, Vol. 111 (E4). [5] Hutton E. W. H. and J. P. M. Syvitski (2008). *Comput. Geosci.*, Vol. 34 (10), 1319-1337. [6] Moratto Z. M., et al. (2010), *41st LPSC*. 2364. [7] Palucis M. C., et al. (2016). *JGR: Planets*, Vol. 121 (3), 472-496.