HYDROCODE MODELLING OF FLUVIAL FLOW WITH *ANSYS CFX*: COMPARISON WITH MARTIAN ANALOGUE LAB-SCALE EXPERIMENTS. M. C. Price[1], S. J. Conway[2], M. C. Towner[3] and M. J. Burchell[1]. [1]School of Physical Sciences, University of Kent, Canterbury, Kent, CT2 7NH, UK (corresponding author: mcp2@star.kent.ac.uk). [2]LPG Nantes, Université de Nantes, 44322 Nantes France. [3]Impacts and Astromaterials Research Centre, Dept. of Earth Science and Engineering, Imperial College, London, UK.

Introduction: We explore the possibility of using *ANSYS' CFX* computational fluid dynamics software [1] to model the flow of water down beds of fine sand (median diameter, d, of 230 µm), medium sand (d=614 µm) and crushed rock (d=1.86 mm) at both Earth and Mars ambient temperatures (293K and 253K respectively) and atmospheric pressures (1000 mbar and 7 mbar respectively). The aim of the project is twofold; firstly to test the applicability of *CFX* (and eventually *FLUENT)* for modelling such systems, and secondly using it to gain insight into observed Martian flow features, such as kilometre-scale gullies by scaling up the model [2,3]. Refinement of the modelling is ongoing and is being validated against a well characterised set of lab-scale experiments [4] which demonstrated that the flow runout length increases with decreasing pressure and temperature due to the freezing of the water at the base of the flow. This effectively decreases the permeability of the granular bed. Careful comparison of modelled to experimental results is giving us confidence in the model parameters and the robustness of the physics built into *CFX*. The aim is to extend the model to include the effect of reduced Martian gravity, phase changes (boiling, sublimation and freezing of the water) and grain size of the sand.

Lab-scale experiments: Multiple experiments (described fully in [4]) were performed under Earth and Martian atmospheric and temperature conditions by pouring water onto a sandbed (1.0 metre long x 0.5 metre wide) at a rate of 0.08 litre s^{-1} for 30 seconds and then carefully measuring the resultant flow channels, sediment erosion and ice formation. The purpose of these experiments was to provide experimental data to better constrain modeling and to provide insight into the factors influencing the erosion, sediment transport and runout of water flowing under Martian conditions.

Modelling: Modelling was performed using version 13.0 of *CFX*. Several different 3-D model setups were investigated involving erosion of the bed, heat transfer between the bed and the water, and the affect of changing the median diameters of the sand particles. Initial modelling (Fig. 1 shows the model setup just before release of water into the chamber) was performed assuming ambient Earth pressure, temperature and gravity conditions (1000 mbar, 293 K, 9.8 ms^{-2}). Water was passed onto the bed (inclined at an angle of 14°) and simulations were run for 30 seconds to match the experiments. Adaptive timesteps were implemented, with a minimum timestep of 0.01 s and the maximum number of iterations per timestep set to 60 to reduce computational time. A patch conforming tetragonal mesh of ~65,000 elements was used to model the entire volume of the sandbox. The model was setup using three Eulerian phases, for air, sand and water.

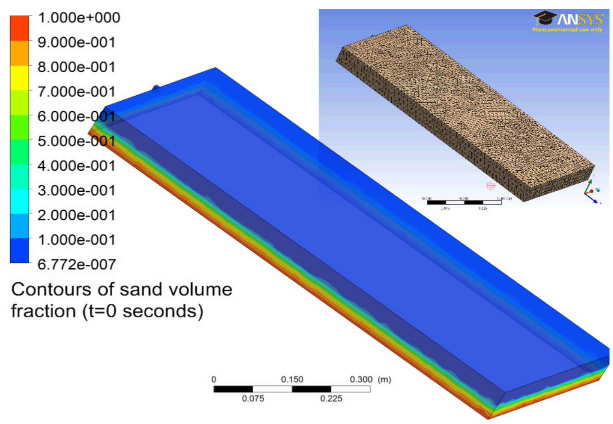

Fig. 1. *CFX* model setup of sandbox at t = 0 seconds just prior to release of water flow from the inlet, showing contours of sand volume fraction and (inset) the tetragonal mesh.

Results: Models were initially run to simulate ambient Earth conditions for comparison with the experimental results given in [4]. The initial aim was to try and reproduce the runout length, *l* (m), channel width, *f* (cm), and the wetted width, *w* (cm), (Fig. 2) as a function of median grain size, *d* (µm). The results are summarized in Table 1 and demonstrate that *CFX* reproduces the same experimental trends (reduction in runout length with increasing particle size etc.).

Table 1: Comparison of results for runout length (*l*) and channel width (*f*) and wetted width (*w*) between experiment (*expt*) [4] and model (*cfx*).

d (µm)	l_{expt}	l_{cfx}	f_{expt}	f_{cfx}	w_{expt}	w_{cfx}
100	-	2.5	-	*	-	*
230	1.4	1.6	4-7	8	10	11
614	0.5	0.8	5-12	10	9	12
1860	1.0	0.6	5-41	13	36	15

*Multiple channels were formed in this simulation with an extended wetting of the sand surface.

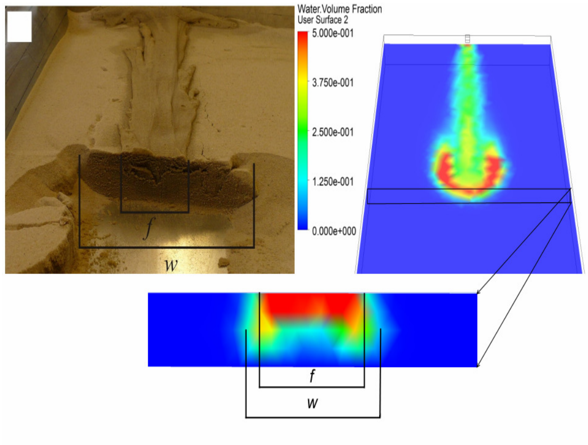

Fig. 2. Comparison of experimental results for a water channel in sand for a median grain size of 230 µm. The bottom-centre diagram is a (truncated) cross-section through the modeled flow showing a similar morphology to experiment with the total wetted width, *w*, greater than the flow width, *f*.

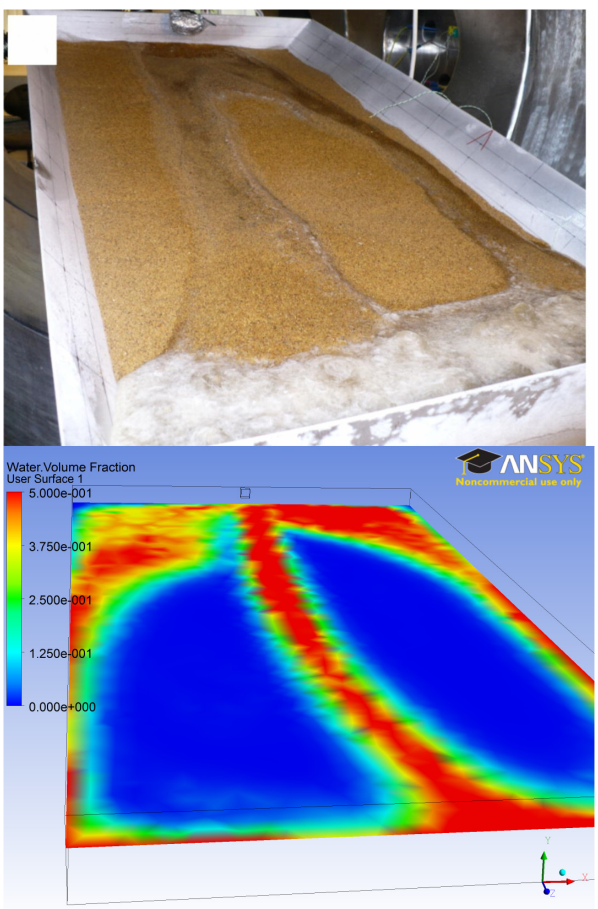

Fig. 3. Top: photograph of experiment showing the formation of two water channels and a central halo. Bottom: simulated flow showing similar formation of halos and multiple channel flow.

Conclusions: The initial results indicate that *CFX* is an ideal tool for modelling fluvial flow under both terrestrial and Martian conditions and not only qualitatively reproduces the features seen in lab experiments (Fig. 2 and 3 – contours shown in the simulated output are of water volume fraction showing the extent of flows/wetting), but also gives quantitative results comparable to those measured, including trends in runout distance, channel width and wetted width as a function of median grain size except for the wetted region for crushed rock which was underestimated (Table 1). This discrepancy is probably due to *CFX* modelling the sand grains as a monodisperse material with a grain size of 1860 µm, but the rock-crush used in the experiments was a polydisperse material, with 80% of grains having a grain size between 100 - 5000 µm.

Future work: Work is ongoing to include heat transport and phase change of water under low pressure and low temperature conditions, and the subsequent effect this phase change has on the runout distance of the water. Experiments show that runout distances are significantly increased due to the freezing of water at a shallow depth in the sandbed. This subsurface ice layer impedes infiltration and causes the flow to propagate faster and further suggesting that flow features on the Martian surface were made by a substantially smaller volume of water than their terrestrial equivalent. The effect of changing the gravity field to Martian gravity will then be investigated as this should increase runout distances further.

All of these models will then be run using ANSYS' *FLUENT* hydrodynamic modeling software package in order to compare *FLUENT* with *CFX.* Additionally, custom liquids will be incorporated into both codes to simulate saturated brines to compare with experimentally determined thermodynamic data [5,6]. Finally, the models will be upscaled to simulate Martian gully formation to constrain the volume of liquid water required to form such features.

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References: **[1]** http://www.ansys.com/products/ fluid -dynamics/CFX/ (accessed Dec. 2010). **[2]** Malin M. C. & Edgett K. S. (2000) *Science*, 288, 2330. **[3]** K. J. Kolb et al., (2010) *Icarus*, 205, 113. **[4]** S. J. Conway et al., (2010) *Icarus*, DOI: 10.1016/j.icarus.2010.08.026. **[5]** A. S. Bagery et al., (2010) *Icarus*, DOI : 10.1016/j.icarus.2010.06.019. **[6]** V. F. Chevrier et al., (2009) *J. of Geo. Res., Planets*, 114. **[7]** http://www.open.ac.uk/science/pssri/ (accessed Dec. 2010).