MODELING THE REACH OF FLOODS IN ATHABASCA VALLES, MARS. C. M. Dundas[1], L. P. Keszthelyi[1], K. E. Williams[1], [1]U.S. Geological Survey, Astrogeology Science Center, 2255 N. Gemini Dr., Flagstaff, AZ 86001, USA (cdundas@usgs.gov).

Introduction: Athabasca Valles has been interpreted as the location of Late Amazonian floods of both water [1, 2] and lava [3, 4]. The surface of the Athabasca Valles Flood Lava (AVFL) includes rootless cones, formed via interactions between lava and shallow water or ice [3, 5]. It has been suspected that floods immediately preceding volcanic eruptions provided the H_2O that caused the rootless cones [e.g., 1, 5], a connection that could be produced if a rising dike breached an aquifer [6]. However, estimated volumes for floods [7, 8] are <100 km^3, around two orders of magnitude less than the ~5,000 km^3 volume of the mapped AVFL [4, 9]. Rootless cones are found on the most distal parts of the AVFL, requiring a flow path of ~1,400 km, far beyond the incised reach of Athabasca Valles. It is thus unclear whether the canonical inferred aqueous floods in Athabasca Valles could be responsible for rootless cones.

The leading alternative is that ice was present in the shallow subsurface from other causes, most likely due to vapor deposition from the atmosphere. Although a recent flood would not be ruled out by this scenario, it leaves open the possibility that the valley incision was done by either much older aqueous floods, or by the AFVL itself and perhaps similar previous flows [4, 9, 10]. Atmospherically emplaced ice is thought to extend equatorward at high obliquity, but published models diverge on whether such ice would be stable near Athabasca Valles at an obliquity of 32–33º [11, 12] or not stable even at 45º [13-15]. Hence, understanding the source of the ice is potentially an important constraint on recent paleoclimate.

Flood Modeling: To understand the possible reach of floods from Athabasca Valles, we are conducting flood modeling using Geoclaw [16]. Geoclaw has previously been used for modeling tsunamis [17] and dam-burst floods [18]. With updates for Mars gravity and radius, Geoclaw produces results for Athabasca Valles similar to other numerical flood modeling codes [19]. Adaptive Mesh Refinement (AMR) allows reduced resolution in areas where no water is present for computational efficiency.

We model a flood that represents a reasonable high-end (high flux and volume) baseline case based on existing estimates [e.g. 1, 7, 8, 19] of flow conditions in Athabasca Valles: a discharge of 2×10^6 m^3/s and a total volume of 84 km^3 in 12 hours. Release of the entire volume at the peak flux is unlikely but intended to maximize the reach of floodwaters. Flux estimates for Martian outflow channels are generally based on bank-full flow in the final eroded channel and thus are almost certainly over-estimates [19, 20]. We consider flow through the existing eroded channel based on Mars Orbiter Laser Altimeter (MOLA) topography. We have tested Manning roughness coefficients of n=0.077 and 0.0545. This latter is the suggested value for Martian grain size distributions from [20] and the latter is a suggested revision with an updated grain size from [21].

Results: After hundreds of hours (Fig. 1) the discharge is over but water is still draining through Athabasca Valles and spreading out into Cerberus Palus. The liquid water depth in Cerberus Palus is only a few meters, with no accounting for losses of liquid to evaporation, freezing, or infiltration. The model has some readily visible, but trivial, artifacts. For example, local lows such as breached craters trap some water. However, some of these traps are due to artifacts in the MOLA DTM, as noted by [19], while some pre-AVFL depressions must have been infilled by the lava.

Our modeling extends roughly an order of magnitude longer than a previous analysis [22] which estimated that an Athabasca Valles flood would have <50 vol. % liquid water after tens of hours. This would greatly affect the rheology and reduce the flow rate; however, that analysis considered erosion of the Valles by a single flood and so may over-estimate the incorporation of eroded material and related cooling. We will present a more detailed analysis of flow cooling and halting at the meeting, similar to some previous analyses [22–24]. Previous studies of water and heat loss from Martian fluvial systems were conducted in one dimension (along-channel). A critical difference here is that it is necessary to consider spreading in two dimensions. This increases the surface area and decreases the depth of water. This effect will be exacerbated because it is unlikely that a stable ice cover will ever form over the entire system, which will accelerate heat loss. For comparison, large areas of terrestrial sea ice have leads (open areas) covering ~3–15% of the total area [e.g., 25]. Moreover, in terrestrial rivers the transition from open water to floating frazil ice and eventually to complete ice cover is velocity-dependent [e.g., 26]. An outflow channel flood would likely be a similarly dynamic and unstable setting and maintain at least some open water until the late stages, which affects mass and heat losses.

Discussion: Based on this preliminary modeling, it appears unlikely that the baseline case for an Athabasca Valles flood was capable of providing water to the locations of the most distal rootless cones, unless heat losses in this slow spreading stage were low enough for flow to continue for many hundreds of hours and the flow was able to become very thin. Additionally, depending on halting time, it is possible that such a flood would have been unable to carve Lethe Vallis. These results are preliminary until we have completed a cooling model.

Acknowledgments: This work was funded by NASA SSW NNH23OB16A. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

References: [1] Burr D. M. et al. (2002) GRL, 29, 2001GL013345. [2] Burr D. M. et al. (2002) Icarus, 159, 53-73. [3] Jaeger W. L. et al. (2007) Science, 317, 1709-1711. [4] Jaeger W. L. et al. (2010) Icarus, 205, 230-243. [5] Lanagan P. D. et al. (2001) GRL, 28, 2365-2367. [6] Head J. W. et al. (2003) GRL, 30, 2003GL017135. [7] Manga M. (2004) GRL, 31, 2003GL018958. [8] Hanna J. C. and Phillips R. J. (2006) JGR, 111, 2005JE002546. [9] Keszthelyi L. P. et al. (2021) USGS SIM Map #3477. [10] Leverington D. W. (2011) Geomorphology, 132, 51-75. [11] Mellon M. T. and Jakosky B. M. (1995) JGR, 100, 11781-11799. [12] Mellon M. T. and Sizemore H. G. (2022) Icarus, 371, #114667. [13] Chamberlain M. A. and Boynton W. V. (2007) JGR, 112, 10.1029/2006JE002801. [14] Steele L. J. et al. (2017) Icarus, 284, 233-248. [15] Aharonson O. et al. (2022) LPSC 53, abstract #2002. [16] Clawpack Dev. Team (2022) Version 5.9.0, 10.5281/zenodo.7026045. [17] LeVeque R. J. et al. (2011) Acta Numerica, 20, 211-289. [18] George D. L. 2011) Int. J. Numer. Methods Fluids, 20, 1000-1018. [19] Keszthelyi L. P. et al. (2007) GRL, 34, 10.1029/2007GL031776. [20] Wilson L. et al. (2004) JGR, 109, 10.1029/2004JE002281. [21] Kleinhans M. G. (2005) JGR, 110, 2005JE002521. [22] Bargery A. S. and Wilson L. (2011) Icarus, 212, 520-540. [23] Wallace D. and Sagan C. (1979) Icarus, 39, 385-400. [24] Carr M. H. (1983) Icarus, 56, 476-495. [25] Wernecke A. and Kaleschke L. (2015) The Cryosphere, 9, 1955-1968. [26] Gosink J. P. and Osterkamp T. E. (1983) Ann. Glaciol., 4, 79-84.

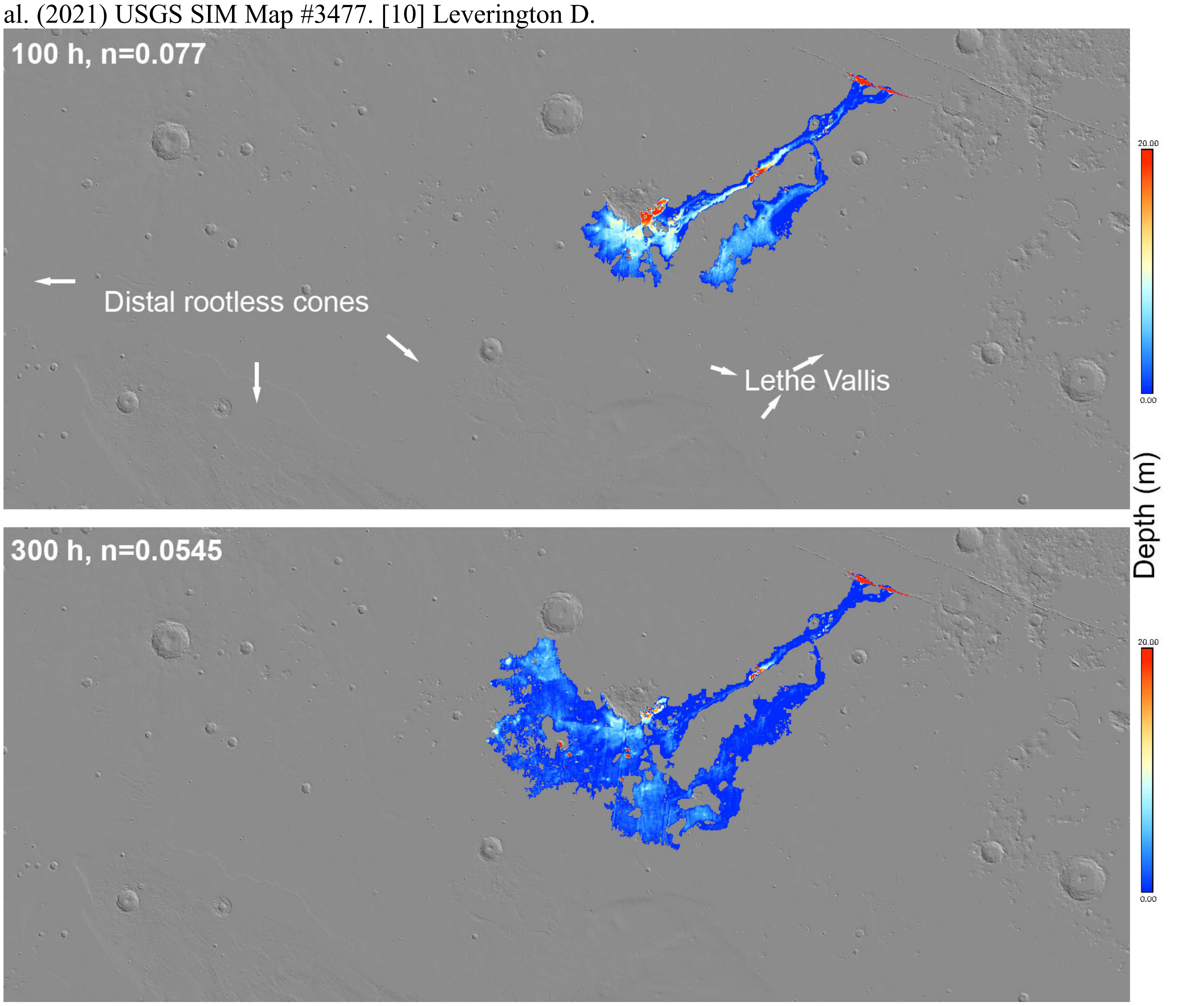

Figure 1: Flood models at various times and with different surface roughness.