ESTIMATING INCISION DEPTH IN MARTIAN VALLEYS: COMPARING TWO METHODS. W. Luo[1], A. D. Howard[2] and J. Trischan[1], [1]Dept. of Geography, Northern Illinois University, DeKalb, IL 60115,, [2]Dept. of Environmental Sciences, P.O. Box 400123, Univ. of Virginia, Charlottesville, VA 22904

Introduction: Extensive valley networks incise the cratered highlands of Mars [*1-4*]. Most of these networks appear to have been most active close to the Noachian-Hesperian boundary [*5-8*], although localized development of valley networks has continued until at least the Hesperian-Amazonian boundary [*9-20*]. Many valley networks record localized incision into broad upland surfaces [*6, 7, 21-23*]. This localized incision may record a late stage of fluvial activity incising into an earlier landscape dominated by local basins and fan systems but little through-flowing drainage [*6, 7, 21*]. The depth of incision would be expected to functionally depend upon the local valley gradient plus the frequency and magnitude of discharges. An analysis of valley depths in the Isidis rim region showed that the depth of valley incision is well predicted by a power function of discharge and valley length (a surrogate for size of contributing area and channel discharge) [*6*]. The regional variation of degree of incision may be informative of climatic variation across Mars at the time of valley network formation. Here we discuss and compare two methods for automatic extraction of depth of valley incision from MOLA data.

Methodology: The critical issues for extraction of valley depth and valley volume are 1) determination of location of valleys to be measured; 2) definition of the reference surface into which valleys are incised; and 3) methodology for querying MOLA data.

Search radius approach (SRA). This method starts with a digitized trace of the valley centerline in geographical coordinates, with points spaced equal to or closer than the valley width. For each point all MOLA point data within a specified radius is accessed and ranked by elevation [*6*]. The valley thalweg is assumed to be the lowest elevation, and the reference surface is assumed to be a fixed percentile of the ranked points (e.g., 75th percentile). This data is then assembled into a valley profile. The profiles need to be interpreted with regard to possible artifacts, such as post-flow craters creating low points or ejecta infilling valleys, or isolated high points within the search radius extending above the reference surface. This approach was used by [*6*] to interpret depth of valley incision in the Isidis region.

Black Top Hat (BTH) transformation. The BTH transformation is an image processing technique originally designed to extract dark areas in a non-uniform background and has been adapted to estimate incision from DEM [*24, 25*]. Operationally, the BTH transformation first finds the maximum elevation from the present-day DEM within a circle centered on a target cell and stores the maximum value as the output for the target cell. The process is repeated until all the cells of the DEM are processed. The result of this step is called dilation. Next, the dilation result is subject to a similar moving-window process, but this time to find the minimum value within the circle. The result is called closing, which represents the DEM of a pre-incision surface. The final BTH result is obtained by subtracting the present-day DEM from the pre-incision DEM [*26*]. The intersection between BTH result and the valley network line (which is derived separately [*4*]) is the depth estimate for the valley network.

Results: We compare the two methods in a general way for the Licus Vallis region (Fig. 1). All of the procedures utilize a 3 km window on a MOLA DEM. The results of the BTH filter are shown in Fig. 1(A). With a 3 km radius the upper portions of Licus Valles is identified, but the lower valley is missed. A wider window would have identified the lower valley. Note that the BTH filter does not identify large impact craters because their width exceeds the search window, but smaller craters are selected. The general approach of the SRA method is utilized in Figs. 1(B&C). Fig. 1(B) plots 0.68 times the elevation standard deviation of the search radius elevations above the mean minus the original elevation. Fig. 1(C) is similar but subtracts the lowest elevation in the search radius, the approach closest approximating the SRA method of [*6*]. Fig. 2 compares the valley depths estimated for a series of points along Licus Vallis. The BTH and the two SRA methods show the same general downstream trends in estimated valley depth. The SRA method in Fig. 1(B) generally gives the smallest estimated depth, the SRA Fig 1(C) method gives the greatest depth, with the BTH method generally in between.

Conclusions: Both BTH and SRA methods provide reasonable estimates of valley depth under most circumstances. For both methods the valley detection and estimates of incision depth and valley volume depend to some degree on the parameters utilized by the procedures. The BTH method parameters are the search radius and the elevation difference threshold for valley detection. The SRA method also utilizes a search radius and a choice of elevation difference expressed as a relative elevation percentile to characterize valley depth. Valleys of different intrinsic width and depth may require specific ranges of method parameters to accurately characterize valley depth and volume. In actual use the SRA method constrains valley recognition through a-priori specification of the valley thalweg. Valley recognition using the BTH approach can utilize post-processing selection of valleys from returned results (e.g. Fig. 1(A)). Both methods require selective interpretation of returned results due to the influence of post-flow craters and other topographic irregularities.

References: [1] Carr, M. H., Chuang, F. C. (1997) *JGR, 102*, 9145-52. [2] Carr, M. H., Clow, G. D. (1981) *Icarus, 48*, 91-117. [3] Hynek, B. M. *et al.* (2010) *JGR, 115*, E09008, doi:10.1029/2009JE003548. [4] Luo, W., Stepinski, T. F. (2009) *JGR, 114*, E11010, doi:10.1029/2009JE003357. [5] Fassett, C. I., Head, J. W. III. (2008) *Icarus, 198*, 61-89. [6] Howard, A. D. *et al.* (2005) *JGR, 110*, doi:10.1029/2005JE002459. [7] Irwin, R. P., III *et al.* (2005) *JGR, 110*, E12S5, doi:0.1029/2005JE002460. [8] Hoke, M. R. T., Hynek, B. M. (2009) *JGR, 114*, E08002, doi:10.1029/2008JE003247. [9] Burr, D. M. *et al.* (2009) *Icarus, 200*, 52-76. [10] Burr, D. M. *et al.* (2010) *J GR, 115*, E07011, doi:10.1029/2009JE003496. [11] Dickson, J. L. *et al.* (2009) *GRL, 36*, L08021, doi:10.1029/2009GL037472. [12] Fassett, C., Head, J. W., III (2006) *Planet. Space Sci., 54*, 370-8. [13] Fassett, C., Head, J. W. (2007) *Icarus, 189*, 118-35. [14] Fassett, C. I. *et al.* (2010) *Icarus, 208*, 86-100. [15] Mangold, N. *et al.* (2008) *JGR, 113*, E08009, doi:10.1029/2007JE002985.[16] Mangold, N. *et al.* (2004) *Science, 305*, 78-81. [17] Morgan, G. A., Head, J. W. I. (2009) *Icarus, 202*, 39-59. [18] Quantin, C. *et al.* (2005) *JGR, 110*, E12S9, doi:0.1029/2005JE002440. [19] Weitz, C. M. *et al.* (2008) *GRL, 35*, L192002, doi:10.1019/2008GL035317. [20] Williams, R. M. E., Malin, M. C. (2008) *Icarus, 198*. [21] Barnhart, C. J. *et al.* (2009) *JGR, 114*, E01003, doi:10.1029/2008JE003122. [22] Jaumann, R. *et al.* (2005) *GRL, 32*, L16203, Doi:10.1029/2005GL023415. [23] Kereszturi, A. (2005) *JGR, 110*, E12S7, doi:0.1029:2005JE002454. [24] Rodriguez, F. *et al.* (2002) *GRL, 29*, doi:10.1029/2001GL014412. [25] Russ, J. C. *The Image Processing Handbook* (CRC Press, Boca Raton, ed. 5th, 2007), 817 pp. [26] Luo, W. et al. (2010) *Geology*, *38*, 335-338, doi: 10.1130/G30816.1

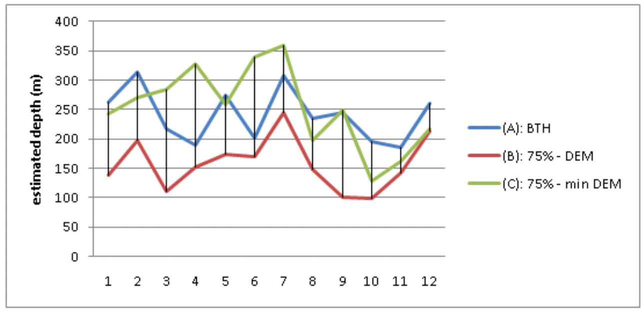

Fig. 2. Valley depth at a series of points along Licus Valles (from downstream to upstream) estimated by the Black Top Hat (BTH) approach (blue line) and two search radius approaches (SRA) (green and red lines).

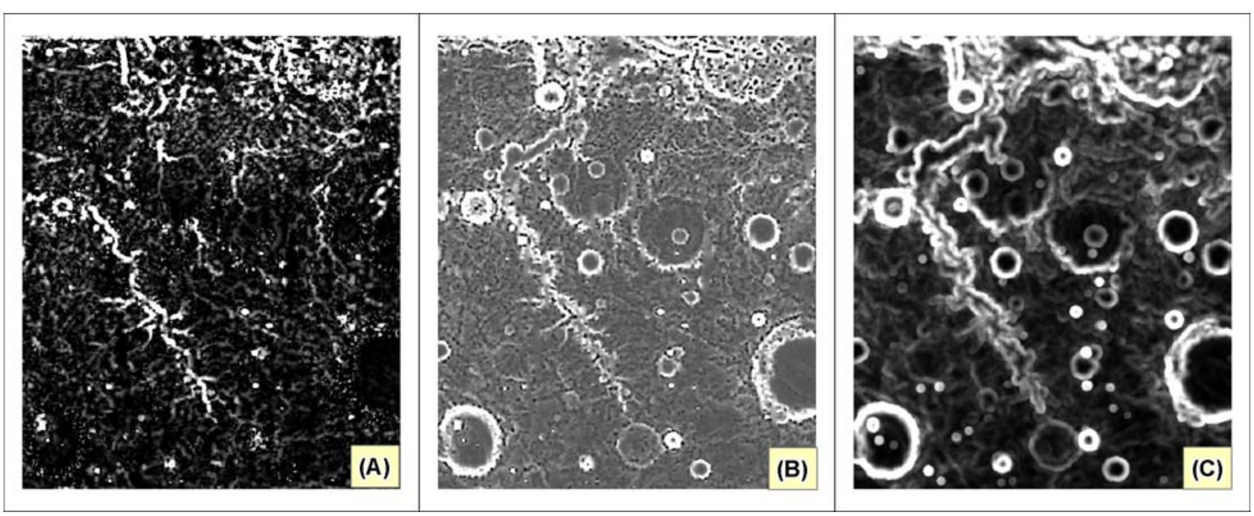

Fig. 1 Valley depth estimation procedures applied to the Licus Valles region, Mars. Bright areas correspond to large depths and also provisionally identify valley locations. All procedures utilize a 3 km search window. (A) Results using the Black Top Hat (BTH) transformation**.** (B) Search radius approach (SRA) using the 75th percentile elevation above the mean elevation within the search radius minus original elevation. (c) SRA approach using the 75th percentile elevation above the mean minus the minimum elevation in the search radius.