**SEMI-THREE DIMENSIONAL COMPUTER SIMULATIONS OF LARGE-SCALE CATACLYSMIC FLOODING: A MODEL AND PARAMETER SENSITIVITIES.** H. Miyamoto[1,2], V. R. Baker[3], and G. Komatsu, [1]Lunar and Planetary Laboratory, University of Arizona (miyamoto@geosys.t.u-tokyo.ac.jp), [2]Department of Geosystem Engineering, University of Tokyo, [3] Department of Hydrology and Water Resources, University of Arizona. [4] International Research School of Planetary Sciences, Universita' d'Annunzio

**Introduction:** Many cataclysmic megafloods in the geological history of Earth has been recognized [e.g., 1-4]. They are linked with late Pleistocene glaciation [5], and therefore research on these floods might provide insights on climatic changes of Earth [6]. Megafloods appear also to have occurred on Mars [7], at scales so large that the outflows may have been responsible for the formation of a transient north polar ocean on the planet [8].

Relevant to these problems, the understanding of discharge rates and durations of megafloods will be quite important. A variety of quantitative methods have been applied [e.g., 9,10]. However, these computations were confined to a single reach at one time. Therefore, it was difficult to reconstruct the continuous flow relationships among multiple reaches, which is necessary to estimate a discharge rate for the whole system of a megaflood.

To solve this problem, we are developing and testing a new semi-three dimensional flood simulation code. The new code is capable of calculating time-slices of flow distribution over topography and depth, and also flow characteristics such as velocity and discharge rate. The combination of topographic data and fluid physics in semi-three dimensions provides important advantages over theoretical analyses or two-dimensional simulations, as follows: (1) complicated water paths, including bifurcations and reconvergences of flows can be naturally reproduced; (2) relationships of individual continuous flow paths can be reconstructed; and (3) calculated areal coverages and water depths can be directly compared with geological and geomorphological observations.

**Theory and numerical scheme:** To describe flood waters in river systems, the Saint-Venant equations, applicable to shallow-water conditions, commpnly appeared in the literature [e.g., 11]. They consist of the mass conservation equation and the momentum conservation equation, as follows (shown here in one-dimension for simplicity):

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+g\frac{\partial h}{\partial x}=g(S_0-S_f), \quad (1)$$

where $u$ is the velocity, $t$ is time, $g$ is the accelelation due to gravity, $S_0$ is the slope, and $S_f$ is the friction slope. Because these equations are too complicated to be solved analytically, various kinds of approximation methods have been developed. We estimated both the kinematic wave and Froude numbers for some major megafloods. Since these values satisfy a criterion given by Govindaraju et al. [11], we adopted the diffusion wave approximation to be the best approach to calculate megafloods.

The frictional term is not easily estimated because it strongly correlates to turbulence and friction at the base, as well as to viscous forces. Therefore, we invoked a widely-used empirical Manning equation,

$$u=\frac{h^{1/6}\sqrt{hS_f}}{n}, \quad (2)$$

where $n$ is the Manning coefficient.

Since we are interested in calculating floods over complicated topography, the numerical scheme is quite important. We adopt the finite difference scheme with the fully implicit expansion of one point upstream. The nonlineality of the basic equation is accommodated by the Newton-Raphson iterative scheme.

We checked our numerical code by comparing analytical results of the full Saint-Venant equations [11,12] and results of 2-dimensional numerical simulations [10, 13] to ensure that our code shows good agreement with previous works.

**Parameters and their sensitivities:** In order to discuss the water movement of an actual cataclysmic megaflood, understanding the relevance of each parameter for the areal spreading of the water is quite important. For this purpose, we calculated many flows in a channel (i.e. without any change in width) under various conditions. These results are quite helpful for understanding parametric performances of a megaflood simulation over a real topography.

We assumed a gentle planar slope, with a size of 100km x 100km, confined on both sides by walls. Water is discharged from a 100km-wide line source, which is located at 30km downslope from the top of the calculation area. We calculated the hydrographs and depths of water at the 50km downslope point from the source line.

*Manning coefficient*: The Manning coefficient is essential to the flow velocity: discharge increases rapidly for smaller Manning coefficients and vice versa. See [14] for more detailed discussion.

*Discharge rate*: Figure 1 shows water depths versus time for different peak flood discharges. Although the discharged water volume and the Manning coefficient are the same, the flood peak water depth and the period achieving the peak depth vary considerably. This result suggests that estimation of discharged water volume is not possible given only evidence from high-water marks in a channel.

*Discharge duration*: Figure 2 shows differences in megaflood hydrographs with different durations of flood discharge. Note that the peak discharge is rapidly achieved and is held constant during the discharge time. This means that the peak water depth in a channel is not strongly influenced by the flow duration. This result also suggests that a discharged water volume for a single channel cannot be estimated from high-water marks alone. Therefore, the reconstruction of complex flow paths and the relationships of individual paths are quite important for estimating discharged water volume for a real cataclysmic megaflood.

**Concluding remarks:** To illustrate the potential of our code, we show a simple application to the Missoula floods (Figure 3). Since our model does not have the channel-specific limitation of the previous model, we calculated flows over the larger area impacted by Missoula flooding. Although several potential problems (e.g., erosion and sedimentation) are not involved in the current version of our model, such a calculation provides a good benchmark of many parameters to compare with field observations. With sufficient attention to appropriate field studies and two-dimensional analysis for each flow path, our method can provide an important means of estimating peak discharges and flow durations for cataclysmic megafloods, which are increasingly recognized as playing critical roles for the past water history of Earth and Mars.

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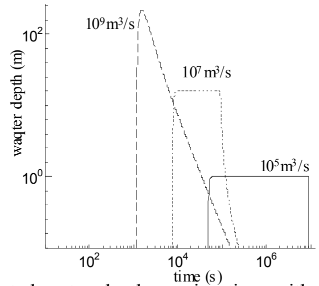


Figure 1. Calculated water depths agains time with different flood peak discharges. Other than peak discharge, various parameters are constant (discharged water volume is $8.64x10^4 km^3$; the slope is 0.01; and Manning coefficient is 0.01). Note that peak water depth and the duration of the peak depth vary considerably.

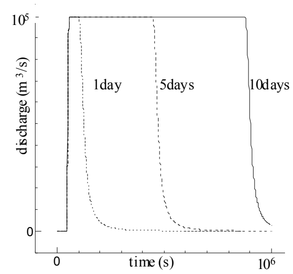


Figure 2. Calculated hydrographs with different durations of flood discharge. Other calculation conditions are kept constant (discharge rate is $10^5 m^3/s$; the slope is 0.01; and Manning coefficient is 0.01). Note that peak discharge rate is shortly achieved and is kept constant during the discharge time.

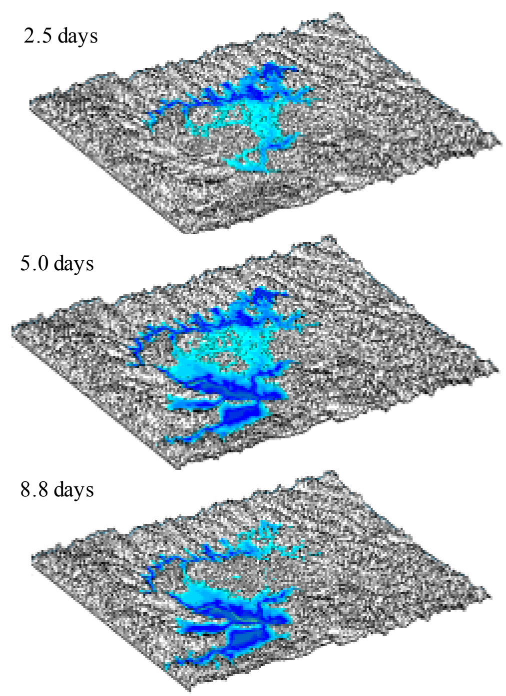


Figure 3. Calculated water advancement against time using current-day DEM of the Channeled Scabland area. Deeper olor represents deeper water depth.