Geophysical Research Abstracts
Vol. 15, EGU2013-5761, 2013
EGU General Assembly 2013

Hydraulics of outburst floods spilling over a steep-walled canyon: Implications for paleo-discharges on Mars

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Canyons carved by outburst floods are common landforms on Earth and Mars. These canyons are generally found in fractured basalts and jointed sedimentary rocks. Flood-carved canyons commonly have steep headwalls and a roughly constant width, and are often thought to have formed from upstream headwall propagation due to waterfall erosion. Because morphology is readily available from satellite imagery, these canyons offer a unique opportunity to quantify the discharge of rare, catastrophic paleo-floods on Earth and Mars. However, mechanistic relationships that relate canyon size to flood discharge have yet to be developed. We propose that the width of a canyon headwall in fractured rock is set by the spatial distribution of erosion around the rim of the canyon, which is controlled by the distribution of shear stresses induced by the overflowing water as it is focused into the canyon head. We test this hypothesis by performing a series of numerical simulations of flood-water focusing using ANUGA Hydro, a 2D-depth averaged, fully turbulent, hydraulic numerical modeling suite allowing for Froude-number transitions. The numerical simulations were designed to explore five dimensionless variables: the aspect ratio of the canyon (length normalized by width), the canyon width to flood-water width ratio, the canyon width to normal-flow depth ratio, the Froude number, and the topographic gradient upstream of the canyon.
Preliminary results show that flow focusing leads to increased shear stresses at the canyon head compared to the sides of the canyon for subcritical floods and higher canyon aspect ratios. This suggests that proto-canyons start growing from a topographic defect in all directions until they reach a critical length for the side walls to dry. Once this critical length is attained, canyons focus most of the flood waters into their heads, and propagate upstream only, maintaining roughly constant widths. Preliminary results suggest that canyon width may be used to reconstruct the discharge of paleo-flood events on Mars and Earth.