Topographic influence on thermo-rheologic modeling of the lava flows of Daedalia Planum, Mars

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Introduction

Modeling provides one method for determining a planetary lava flow's rheology (e.g., yield strength, viscosity) and eruptive properties (eruption rate) with limited data. Input variables for these models include the dimensions of the flow and topography over which it flows. The topography of the flow is accounted for by the underlying path slope of the flow which is assumed to be equal to a regional path slope taken near the flow as shown in Figure 2. The question this study examines is how variances in this slope caused by the choice in path slope will effect the model results.

Background

- Modified model input variables to planetary specific values (gravity and atmospheric properties) along with assumed initial terrestrial rheologic properties to make the model applicable to Mars.
- The study site is 370 km south of Arisa Mons in the Daedalia Planum, Mars as shown in Figure 1.
- The study region has an average slope of less than 1° and flows in this region may represent the youngest flows on the planet (Smith et al., 1999; Crown and Ramsey, 2016; Crown et al., 2015).
- The slope of the region was derived from the DEM interpolated from the elevation data provided by the Mars Orbiter Laser Altimeter (MOLA) instrument. The DEM has a horizontal special resolution of 100 m and a vertical resolution of ~3 m (Smith et al, 2003).

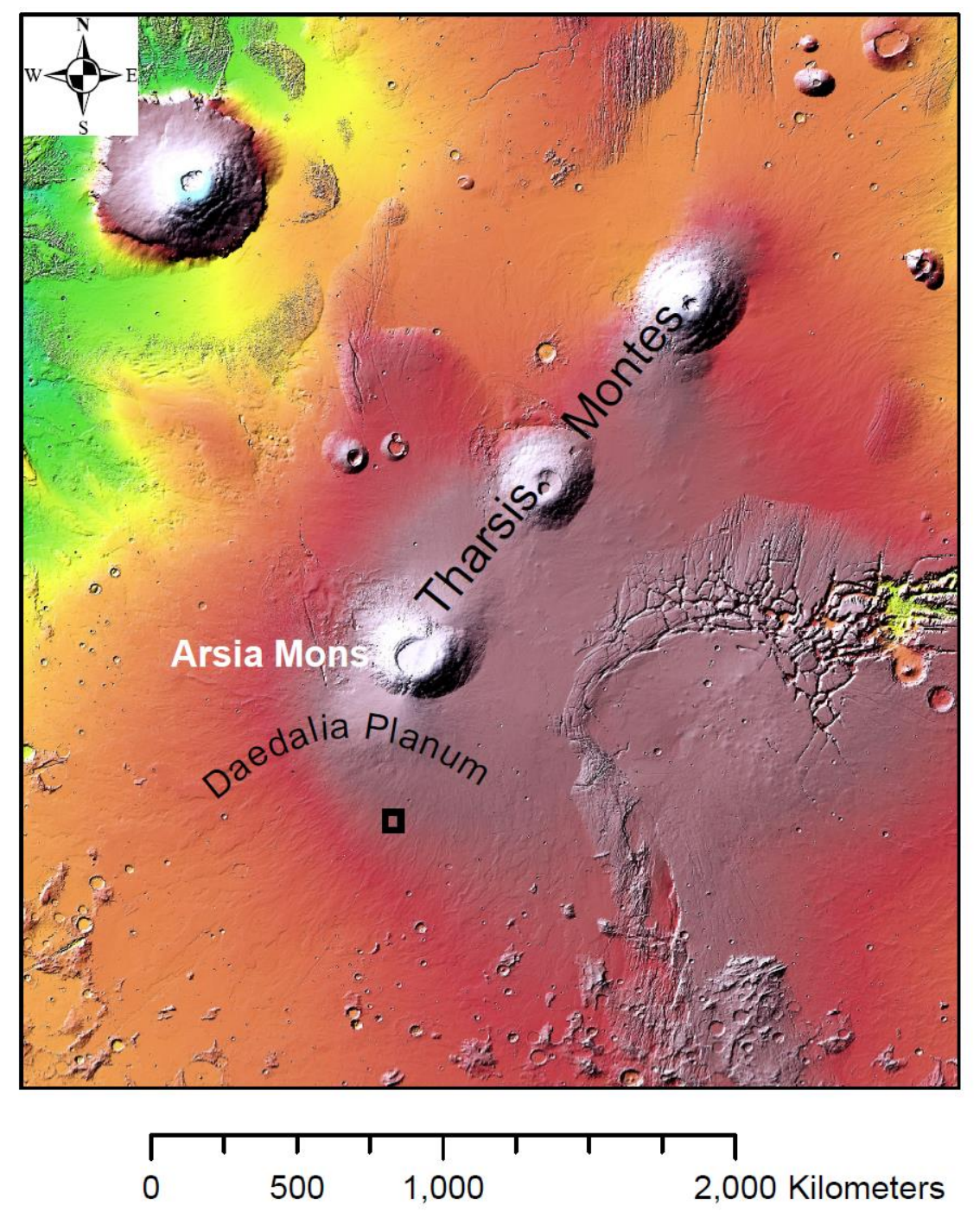

Figure 1: Figure of Tharsis region made of a subset of the MOLA Global Colorized Hillshade dataset with the region shown in Figure 2 outlined in black (Smith et al., 2003).

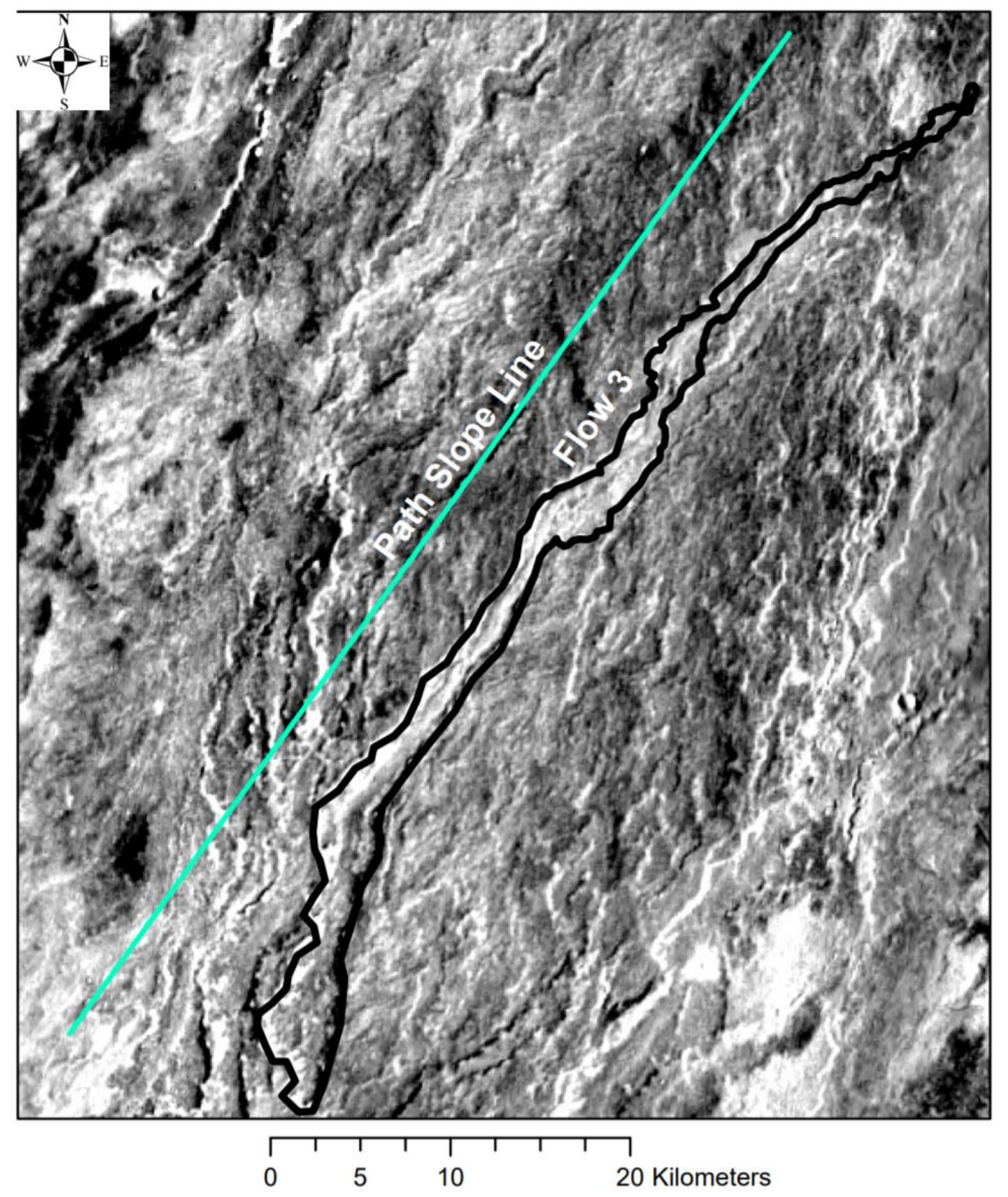

Figure 2: Image of Flow 3 discussed in this study with outlines of the flow and the slope path.

FLOWGO Model

- Cooling limited thermo-rheological model that terminates when the flow velocity reaches zero due to rheologic changes or temperature goes below the solidus (Harris and Rowland, 2001).
- Velocity is a function of slope, gravity and rheology.
- Model parameters, including slope and rheological properties, are re-calculated at each model iteration.

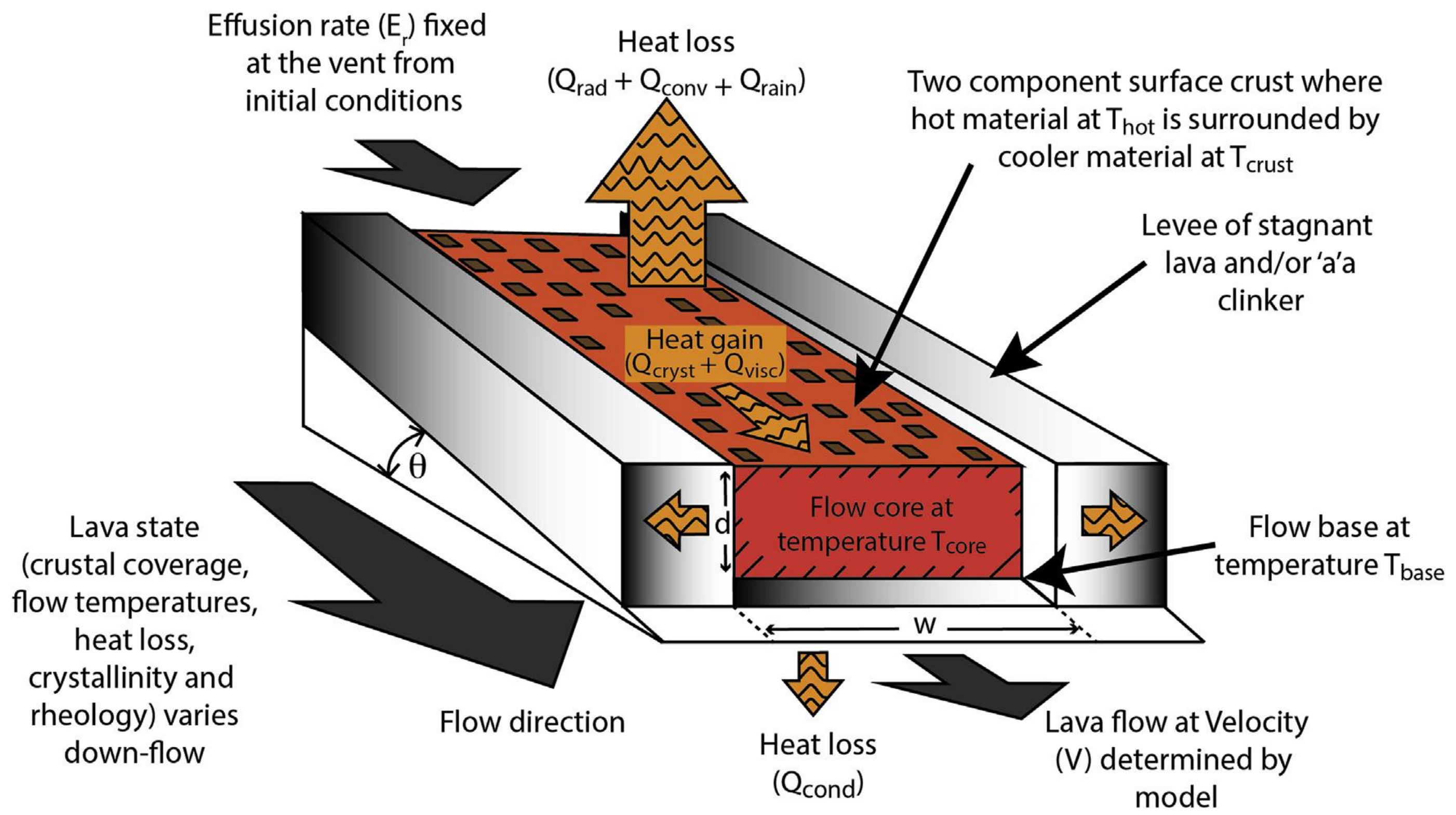

Figure 3: Figure that summarizes the flow structure assumed for the FLOWGO model (Chevrel et al., 2018).

Methods

- An initial control model was produced setting all slope values to the flow's average slope of 0.642°. This is done to remove slope variations and determine how this effects the modeled flow length.
- Set slope variation of 0.1° were then placed at specific points along the flow path to examine their effect under controlled conditions while all other model parameters are held constant.
- Variations set at 0.1° as this is a uncommon slope value in the region.

Results

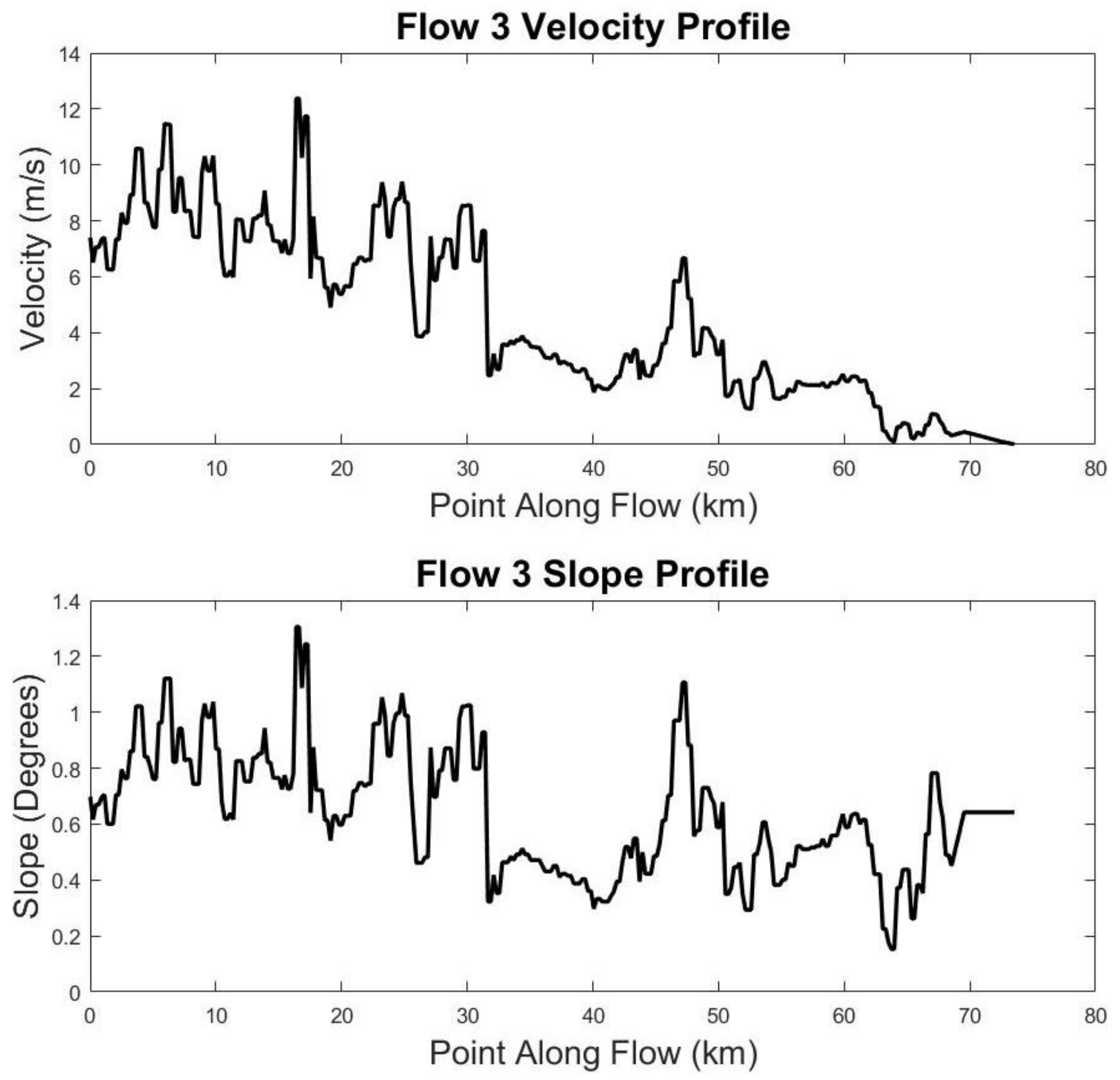

Figure 4: Plot of the variations in in flow velocity (4a) and path slope (4b) along the flow length for Flow 3.

- Figures 4-5 show that the model velocity and resulting flow length are directly proportional to the slope.
- Removing the slope variations cause the modeled flow length to increase by ~60 to over 200%.
- Figure 6-7 show that adding shallow variations in the slope causes a decrease in flow length (control length of 87.1 km). As the length of the variation increases there is an abrupt reversal this relationship at 4.96 km. The two relationships are separated in the plot for clarity.

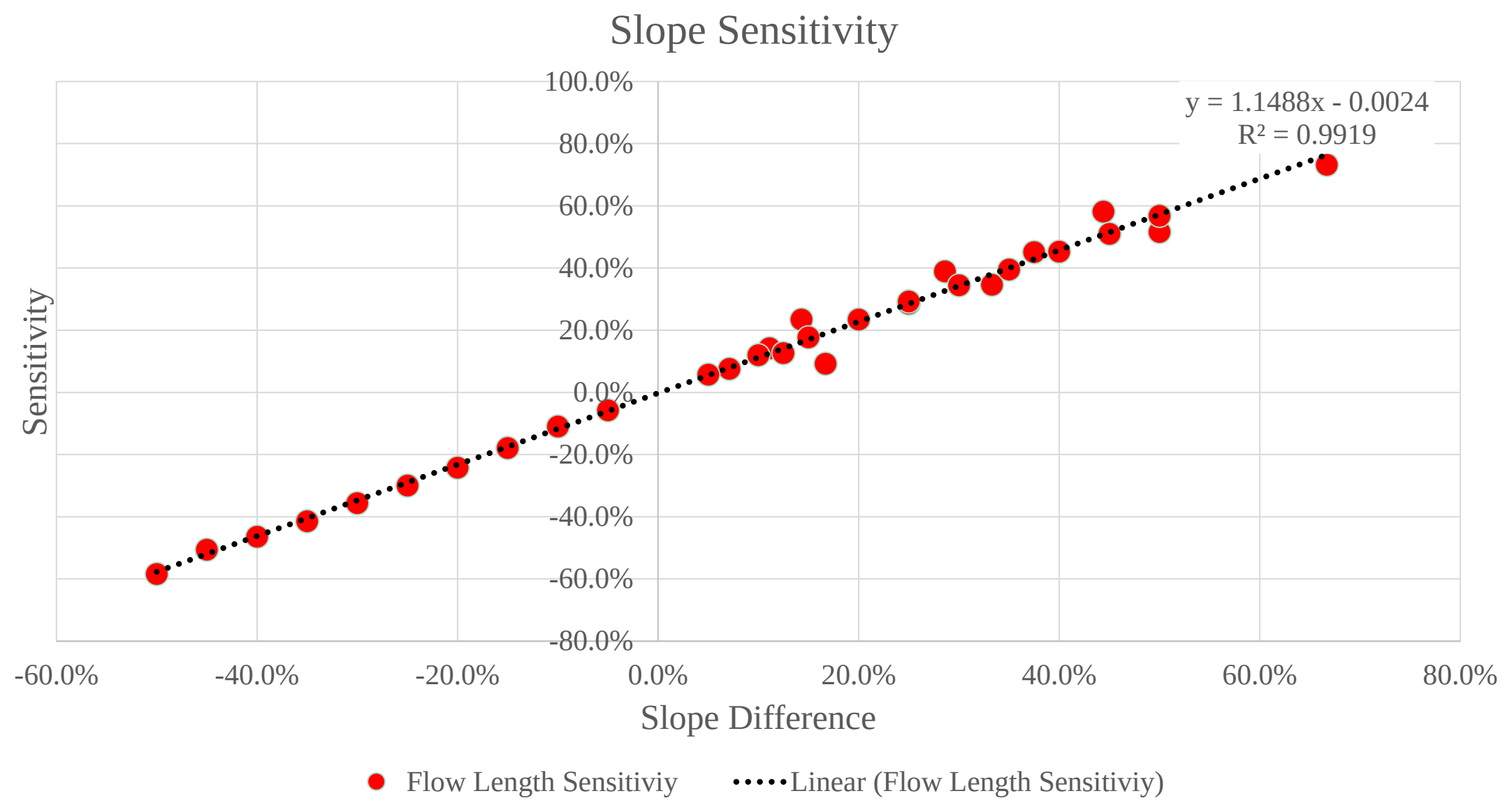

Figure 5: Plot of the sensitivity of modeled flow length caused by varying the constant path slope. Sensitivity based on the percent change of the value from that the constant average slope.

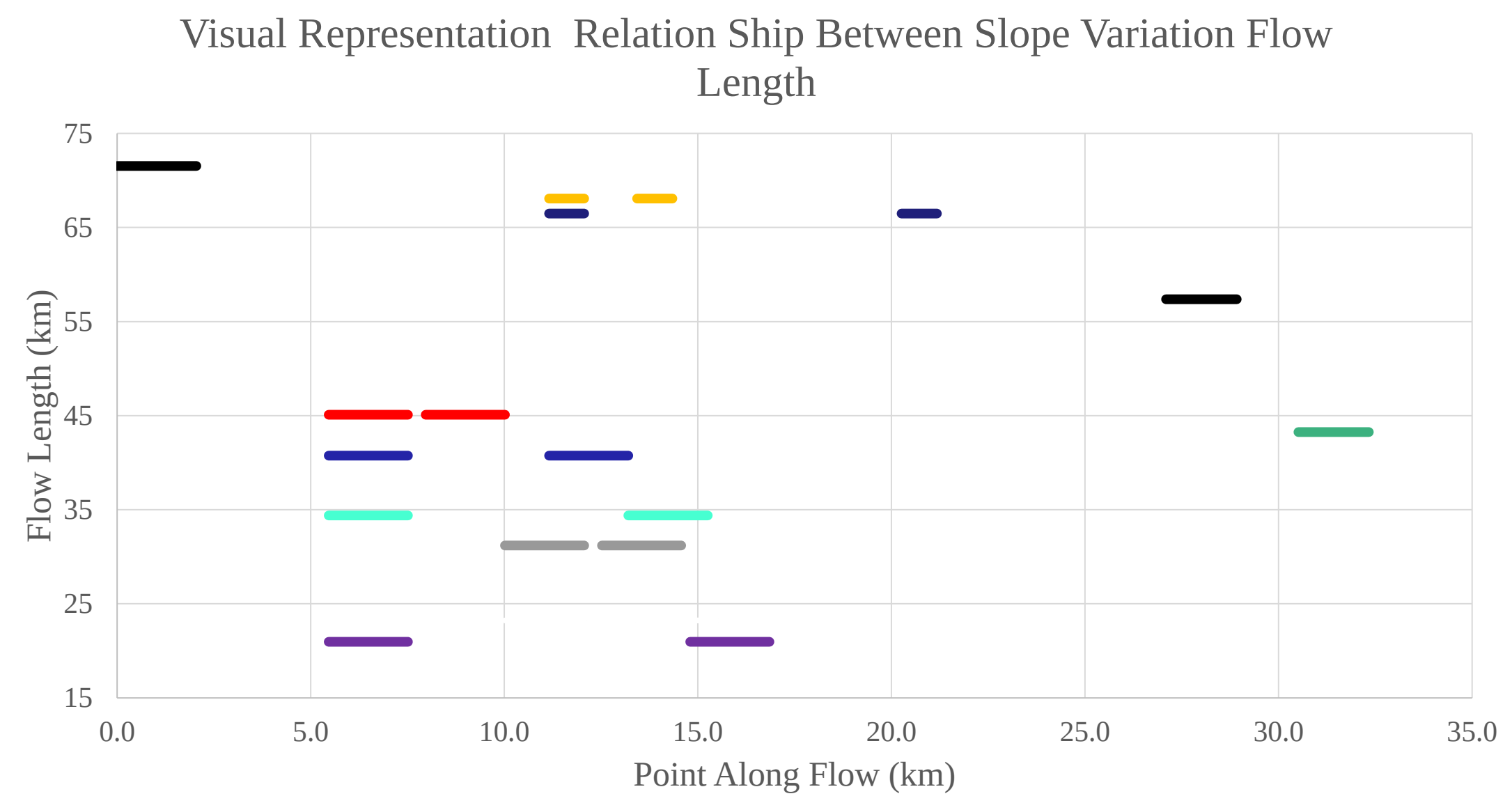

Figure 6: Plot giving a visual representation of the locations and length of slope variations and subsequent modeled flow length.

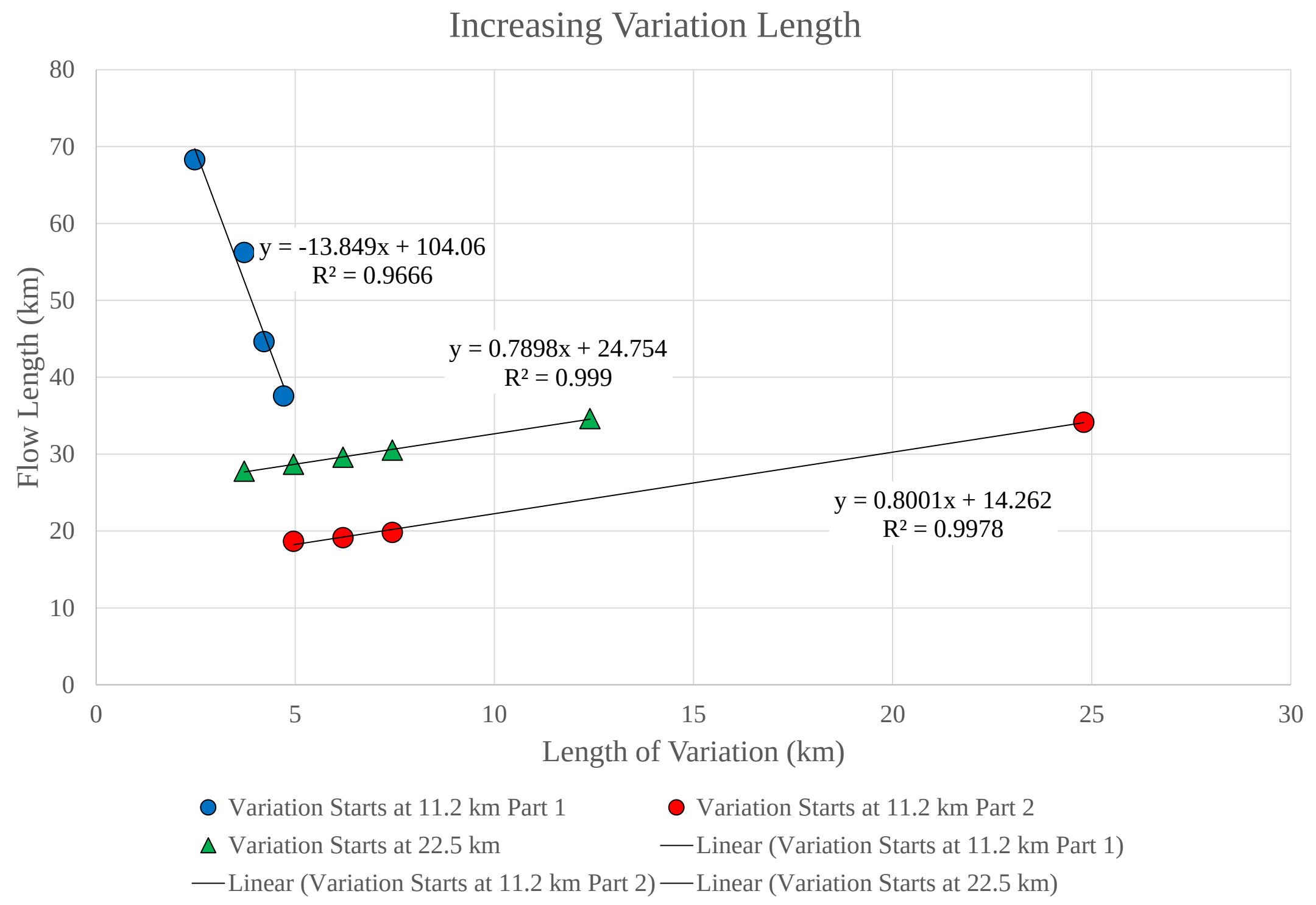

Figure 7: Plot of the variations in in modeled flow length as the length of a single shallow slope variation is increased. The shallow regions start at different points along the flow as indicated in the legend and with a slope of 0.1°.

- Figure 8 and 6 show that the modeled flow length decreases with an increase in separation distance between two low slope variations.
- This result indicates that having several such small size variations can have an effect similar to one long variation.

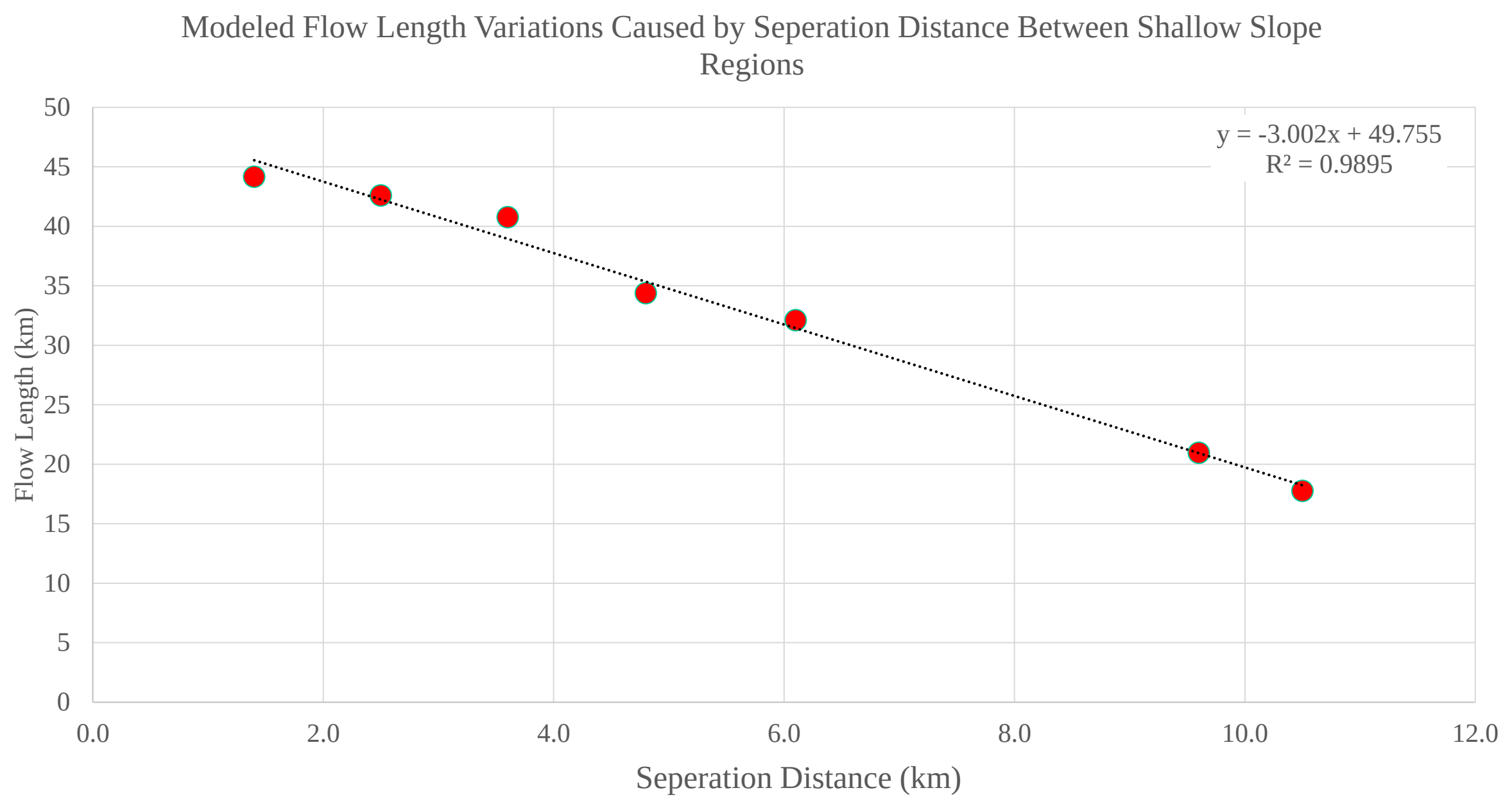

Figure 8: Plot of the variations in in modeled flow length as distance between two shallow slope regions is increased. The shallow regions are each 2.28 km long and have a slope of 0.1° with the separation starting at 12.3 km from the start of the flow.

Conclusions

- Removing slope variation causes flow length to increase by about 60 to over 200 percent depending on the flow investigated. This result indicates that variations in slope that shallow are an important aspect of flow modeling as higher angle variations would cause an increase in flow length.
- Slope variations need to be of sufficient length to strongly effect flow length. This indicates that the choice of data sets must be considered as having slope data separated by a spatial resolution greater than this critical length will strongly effect model results.
- The positon of slope variations greatest effect on flow length near the end of a flow. This indicates that reviewing of end data points are more important then near the start of the flow.
- Having two shallow variations separated by a distance causes a greater effect on the modeled flow length than only a single longer stretch of shallow slope.
- To summarize this studies findings, variations in flow slope have a strong effect on the modeled flow length with position, size, and separation between variations determining the magnitude and direction (increase or decrease) of this effect.

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