Forte, A.M., Whipple, K.X., and Cowgill, E., 2015, Drainage network reveals patterns and history of active deformation in the eastern Greater Caucasus: Geosphere, v. 11, doi:10.1130/GES01121.1.

**SUPPLEMENTAL TEXT**

(http://dx.doi.org/10.1130/GES01121.S1)

**Landscape Evolution Modeling**

Schematic diagrams of the 13 different uplift scenarios tested with the FastScape landscape evolution model are illustrated in Figure S3 along with the final model output. Model names indicate the scenario being tested and are then numbered in the order in which they were run. As indicated in the main text, resolutions of the models are all identical and the dimensions are all the same except for the *Dagestan-1* and *Dagestan-2* models. For each model, the 260 km model width was divided into 20 sections and locations of prescribed changes in the uplift functions were given in reference to these divisions.

Two different initial topographies were tested. One initial topography was a simple condition set at 0 meters and the other which used a pre-existing channel network developed as a restart point for the models as described in the main text. In Figure S1, we compare the results of the two models (*North-5* and *South-3*) that are considered the exemplar models in the main text using these two different initial topographies. The overall form of the topography (e.g. location of topographic crest, divide, etc) is largely similar, but the channel network is distinctly different between the two, with the models using the dendritic initial topography having channel networks that are more realistic. Within the main text and in Figure S3 we present the results using this dendritic initial topography. The initial topography for all models is shown in Figure S2.

For the initial uplift peak ($U_1$), a gradient in uplift rate was implemented such that uplift reached zero at both the northern (x = 260) and southern (x = 0) model boundaries. The rate decreased from the maximum toward the model edges either as a simple linear decrease, decreasing with the square of distance away from the peak, or decreasing as the cube of distance away from the peak. The gradients away from second uplift peak ($U_2$) were set to decrease to a rate either equal to the background rate from the first uplift peak or to zero, depending on the exact geometry of the second peak.

For models that incorporate lateral propagation, this was implemented by applying a negative square term within the uplift function, giving the uplift a concave down, parabolic shape in the y-direction of the model, reaching the maximum in the center of the model (Figure S3). For most of the models, this was done with maximum uplift rate (peak of the parabola) restricted to 50% of max in the early stages of the model. The width of this parabola was incrementally increased until a nearly linear profile in uplift rate was achieved, and then the uplift rate increased to 100% of max synchronously along-strike. For *South-3*, *South-4*, and *North-5* this was modified with a 50%, 75% and finally a 100% condition during the lateral propagation process. Below we discuss the details of the individual models, with the uplift rate displayed graphically in Figure S3 along with final topographic output. We also include the input files for each model as text files. To run the models in FastScape the file names should be changed to

"FastScape.in" and placed in individual folders with a five character long name. The name of the folder is then called from the terminal and run in FastScape in expert mode per the instructions included with the FastScape model. Times for events within the models within these input files are give with respect to a start time of 0, however to run these models as shown in the main text and Figure S3, one would need to 1) run the Initial Topography model, 2) place the "RESTART" file generated at the end of this model run in the folder of the model of interest, 3) add the flag "restart=1" to the input file for the model of interest, 4) change the total run time to be 100 Ma plus the desired run time (to account for the 100 Ma that the initial topography model has already run) and 5) similarly add 100 Ma to the timing of all individual events within the model input file.

***Stationary-1***

*Model Setup:* Model tests a scenario with no across-strike (x) propagation. Both zones of uplift do propagate laterally (y) and the whole uplift proceeds similar to the initial phase of uplift in model *North-5* and *South-3* with a 50% phase, a 75% phase and then a maximum phase. Position of $U_1$ is 104 km and position of $U_2$ is 143 km. The final uplift function is identical to the final function for *North-5*. The magnitude of $U_1$ is less than that of $U_2$.

*Model Result:* Fails to separate drainage divide and topographic crest, with both features localized near the northern zone of uplift throughout most of the model domain. Also fails to produce longitudinal drainages for north-flowing rivers.

***Stationary-2***

*Model Setup:* Model tests a scenario with no across-strike (x) propagation. Setup is identical to *Stationary-1*, except the magnitude of $U_1$ equals that of $U_2$.

*Model Result:* Fails to separate drainage divide and topographic crest, with both features alternating between being localized with the northern and southern uplift zones. The model does produce some longitudinal drainages within the population of north-flowing streams, but these do not match the channel networks observed in the east-central Greater Caucasus.

***South-1***

*Model Setup:* Model tests a southward migration scenario. Initial model conditions prescribed lateral propagation of an initial, northern peak in uplift with a flat top. During lateral propagation, the maximum uplift is 50% of the eventual maximum uplift $U_1$. The second, southern uplift peak also laterally propagates, but the center part of the southern peak experiences the maximum uplift rate immediately. The maximum uplift rate of this second peak, $U_2$, is equal to $U_1$. Position of $U_1$ is 104-117 km and position of $U_2$ is 143-156 km.

*Model Result:* Successfully reproduced curved drainages similar to the main stem of the Samur river system, but topographic crest and drainage divides are coincident.

***South-2***

*Model Setup:* Model setup and implementation is largely similar to model *South-1*, the main difference being the geometry of the northern uplift peak. In this model, the northern uplift peak is broader and with a non-varying rate over ~90 km. Position of $U_1$ is 104-117 km and position of $U_2$ is 143-208 km.

*Model Result:* Successfully reproduced curving drainages on northern side of the range, but produced an unreasonably large zone of high elevation topography in the center of the range. Drainage divide and topographic crest are also largely coincident. Curving drainages are produced along the southern margin of the range as well, which are observed in some regions of the Greater Caucasus, but not in the portion of the eastern Greater Caucasus under consideration.

***South-3***

*Model Setup:* A southern migration scenario testing more discrete peaks in maximum uplift rates than in many of the previous models. Both zones of uplift migrate laterally and the initial northern zone of uplift has a more complicated uplift history with an initial phase at 50% of max, a penultimate phase of 75% of max and then reaches maximum, all during the lateral propagation phase. The magnitudes of the two uplift zones are equal in this model. Position of $U_1$ is 104 km and position of $U_2$ is 143 km.

*Model Result:* Northern drainage network reproduces some aspect of eastern Greater Caucasus but lacks significant longitudinal drainages or south-flowing drainages. Topographic crest and drainage divide are not separated, instead a separate line of peaks exist along the southern zone of uplift.

***South-4***

*Model Setup:* Similar in locations and general form of uplift as model *South-3*, but with a southern zone of uplift much larger than that of the northern zone. This model was specifically designed to test how much larger the magnitude of the southern uplift zone needed to be to initiate a drainage reversal. Presented result has magnitude of southern uplift double that of the northern uplift. Position of $U_1$ is 104 km and position of $U_2$ is 143 km.

*Model Result:* Successfully produces a southern drainage divide location and a southern drainage network largely similar to what is observed in the eastern Greater Caucasus, but divide is coincident with topographic crest. Northern line of peaks created by northern zone of uplift are smaller and more isolated than topographic crest or what is observed in the eastern Greater Caucasus.

***North-1***

*Model Setup:* This model tests a northward migration scenario. Initial uplift of the southern peak occurs via lateral propagation, similarly implemented as in the preceding models. The later northern uplift zone occurs synchronously along-strike and is implemented with a continuous, linearly increasing uplift rate from $U_1$ to the higher $U_2$. Position of $U_1$ is 104km and position of $U_2$ is 156 km.

*Model Result*: Model reproduces drainage divide along the southern margin of the high topography of the range and curving drainages along the northern margin of the range. Topographic crest and drainage divide are not particularly distinct from each other and southern rangefront is characterized by secondary peaks south of the drainage divide, which is not observed in the eastern Greater Caucasus.

***North-2***

*Model Setup:* Model setup is very similar to *North-1*, but in this model, the southern, initial uplift zone initiates synchronously along-strike and the northern uplift zone propagates laterally. Position of $U_1$ is 104 km and position of $U_2$ is 156 km.

*Model Result:* Southern drainage divide and structure of drainage network largely similar to eastern Greater Caucasus, but topographic crest and drainage divide not as distinct as observed in the real topography. Northern drainage network lacks curved drainages or significant segments of longitudinal or south flowing drainages as observed in the eastern Greater Caucasus.

***North-3***

*Model Setup:* Largely similar to model *North-2*, the primary difference being that the two uplift zones are more discrete, with a region of relatively low uplift rate between the two peaks. As in models *North-1*, and *North-2*, the maximum rate of uplift of the northern zone, $U_2$, is greater than $U_1$. Position of $U_1$ is 104-117 km and position of $U_2$ is 143 km.

*Model Result:* Southern drainage network approximates that of eastern Greater Caucasus and topographic crest and drainage divide largely separate. However, drainage network of northern drainages lacks curving drainages and south flowing segments. Also, region between the drainage divide and topographic crest is high elevation and relief, unlike in the eastern Greater Caucasus.

***North-4***

*Model Setup:* Geometrically identical to model *North-3*, but in this model both zones of uplift propagate laterally. Position of $U_1$ is 104-117 km and position of $U_2$ is 143 km.

*Model Result:* Drainage network of northern drainages shares many first order characteristics with eastern Greater Caucasus, but southern drainage network contains too many longitudinal drainages. Additionally, area between the topographic crest and drainage divide is high elevation and high relief.

***North-5***

*Model Setup:* A final northward migration scenario. Both zones of uplift propagate laterally and the initial southern zone of uplift proceeds similar to the initial phase of uplift in model *South-3* with a 50% phase, a 75% phase and then a maximum phase. Position of $U_1$ is 104 km and position of $U_2$ is 143 km.

*Model Result:* Reproduces most first order characteristics of the eastern Greater Caucasus. Drainage divide lies along southern margin of the range and southern drainage network largely comparable to the eastern Greater Caucasus. Northern drainages traverse a separate topographic crest with examples of longitudinal and south-flowing drainages. Area between topographic crest and drainage divide is higher relief/more incised than in the eastern Greater Caucasus.

***Dagestan-1***

*Model Setup:* A northern propagation scenario, but testing a zone of uplift more analogous to the position of the Dagestan thrust belt. The southern zone of uplift initiates first, synchronously along-strike and is larger in magnitude. The second zone of uplift $U_2$ is smaller in magnitude than $U_1$. Position of $U_1$ is 143-156 km and position of $U_2$ is 221 km.

*Model Result:* Produces a zone of largely undissected, high elevations between the northern zone and southern zone which is inconsistent with the eastern Greater Caucasus.

***Dagestan-2***

*Model Setup:* Identical to *Dagestan-1* but with lateral propagation of both the southern and northern zones of uplift. Position of $U_1$ is 143-156 km and position of $U_2$ is 221 km.

*Model Result*: The zone of high uplift observed in Model *Dagestan-1* is slightly more dissected, but still does not satisfactorily reproduce the topography of the eastern Greater Caucasus.

## Figures

***Figure S1***

Comparing the final time-steps of models *North-5* and *South-3* using a flat initial topography (left), versus a low-relief landscape with a south-flowing dendritic channel network, shown in Figure S2 (right). For the majority of the main text and supplement, we only discuss the models using the initial dendritic channel network topography.

***Figure S2***

Final topography after running a model for 100 million years of dimensions x=260 km and y=500 km that drains to the south (x=0) with an uplift rate of 0.01 mm/yr. This final topography was used as the initial topography for all of the presented models.

***Figure S3***

Schematic representation of the uplift rates imposed for the various model scenarios tested, viewed in north-south orientation with respect to the Greater Caucasus. Black lines indicate initial geometries, grey lines indicate portion of the geometry that is different after initiation of second uplift zone. Concentric circle symbol indicates lateral propagation was implemented and dotted lines indicate the partial uplift rates implemented during these lateral propagation periods. Relative differences between the maximum value of the two uplift rates, $U_1$ and $U_2$ are given. Geometry of uplift rate gradient is labeled as either, “c” for a rate that decreases with the cube of distance, “s” for a rate that decreases with the square of distance, or “l” for a linear decrease with distance as described in the supplemental text. Below each uplift function is the output topography of the final timestep of the model. Final panel shows schematic of time-steps in the lateral propagation function. For this panel, the view is 90 degrees from the other diagrams, approximately east-west in terms of the Greater Caucasus.