Modeling long-term progressive erosion at the West Valley site

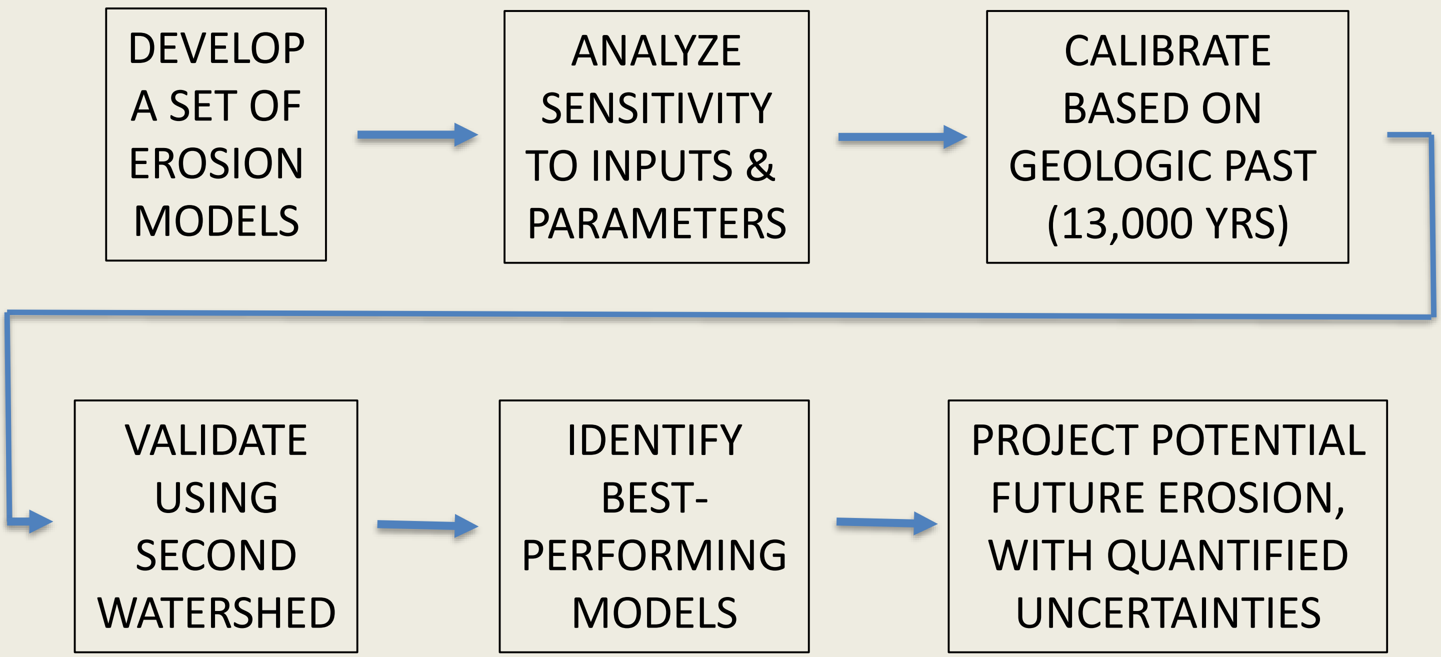
Erosion Working Group modeling team:

Gregory E. Tucker[1], Katherine R. Barnhart[1], Sandra G. Doty, Rachel Glade[2], Mary C. Hill[3] , Matthew Rossi[1], Charles M. Shobe[1]

1 – CIRES and Department of Geological Sciences, University of Colorado, Boulder
2 – INSTAAR and Department of Geological Sciences, University of Colorado, Boulder
3 –Department of Geology, University of Kansas

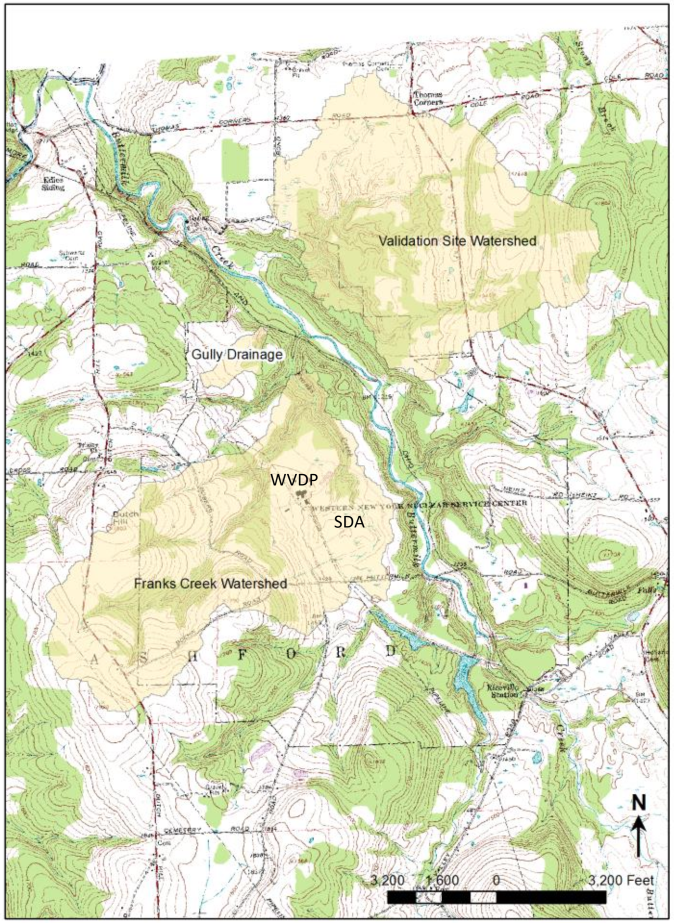
West Valley Quaterly Public Meeting, February 28, 2018

Approach involves six major steps

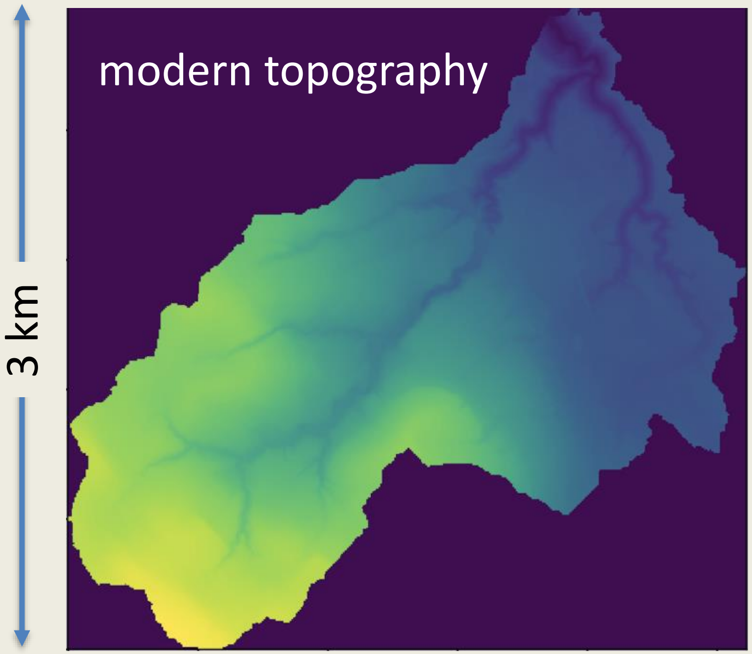


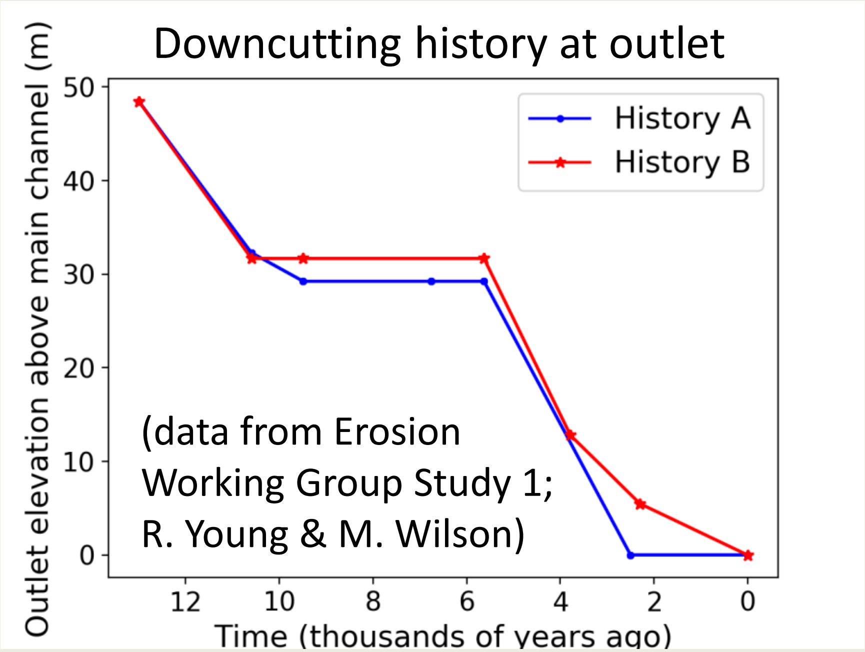
Models simulate long-term erosion at gridded locations in a drainage basin

- Developed 37 process models
- Each model incorporates:
  - Mass movement
  - Hydrology
  - Channel/gully erosion
  - Material properties
- Grid resolution is 24’

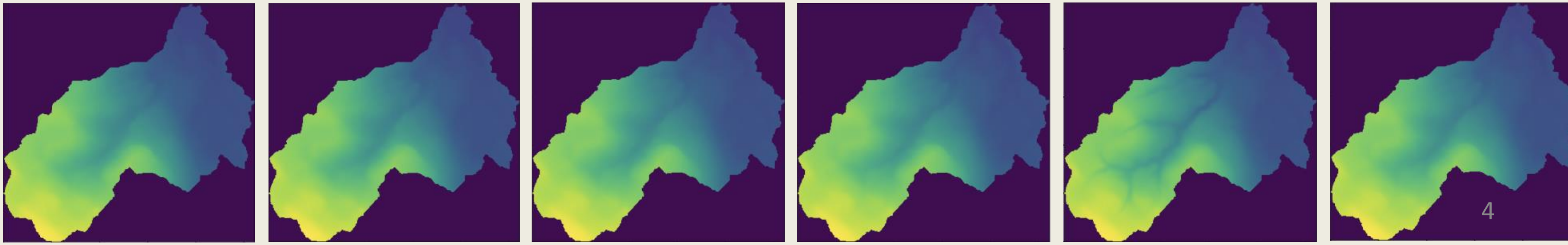


Erosion Working Group Study 1 data allow reconstruction of past topography and downcutting history

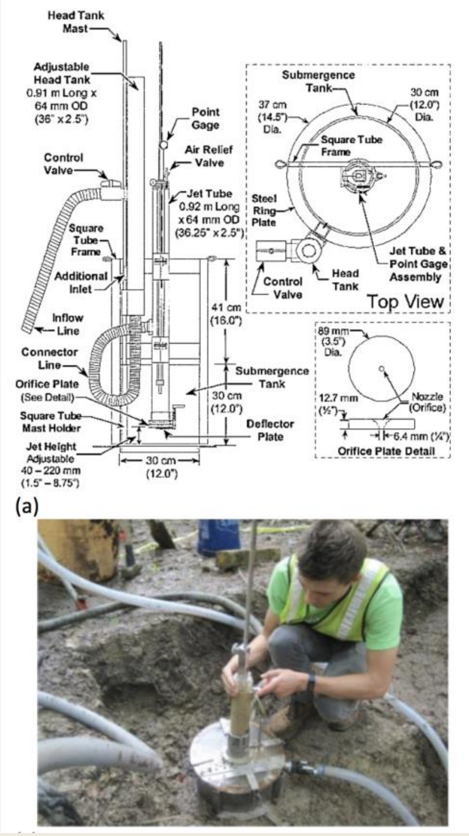




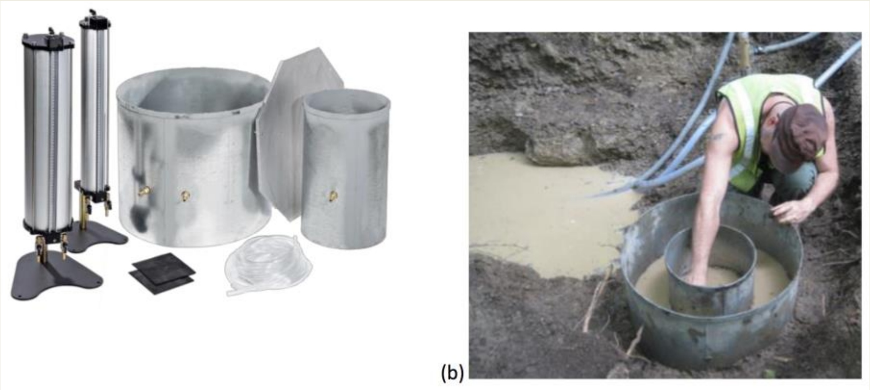
alternative reconstructions of paleo (~13 ka) topography, with post-glacial ravines filled in



Input parameter ranges are informed by results from Erosion Working Group field studies



Soil / till erodibility

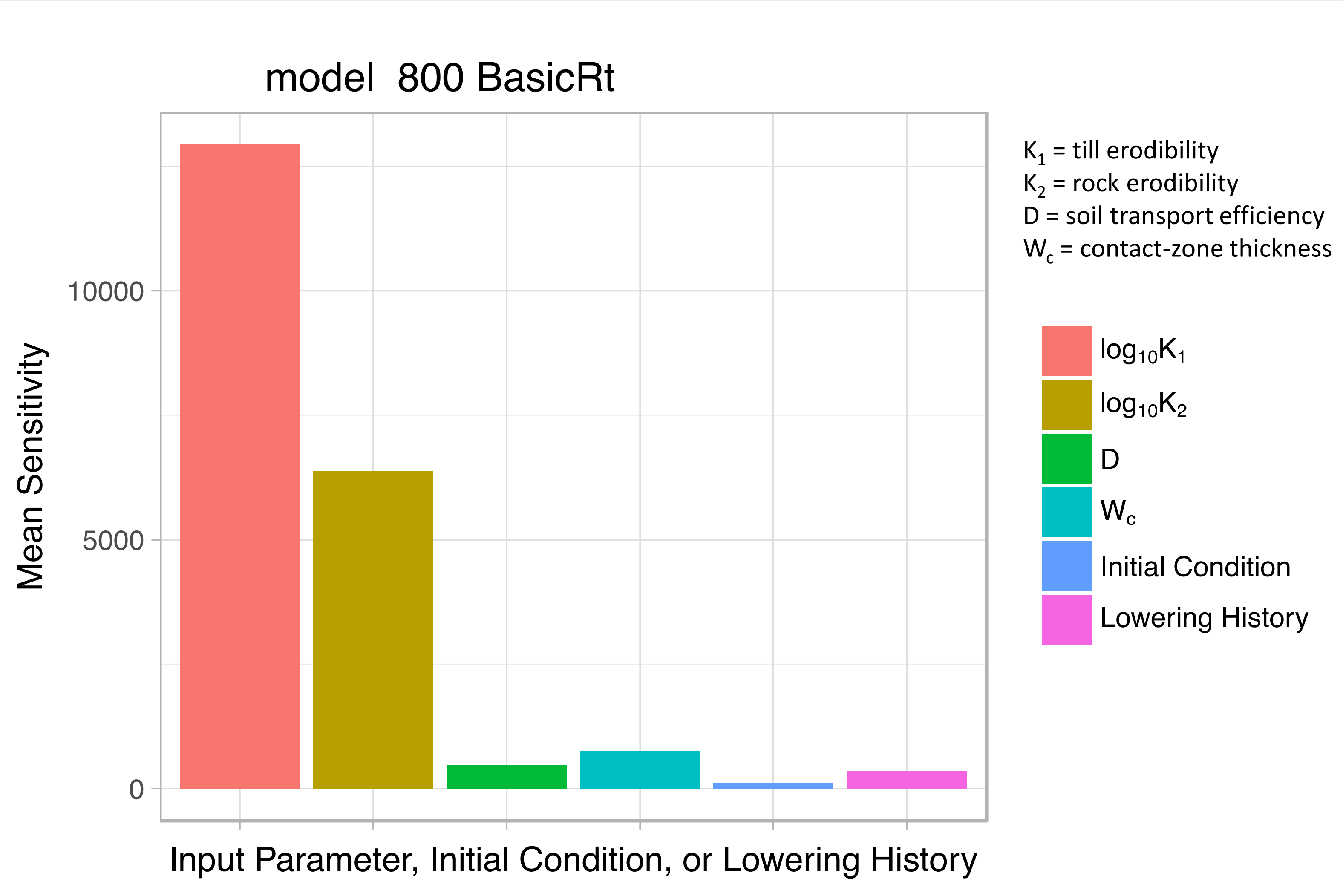


Soil infiltration capacity

Channel grainsize

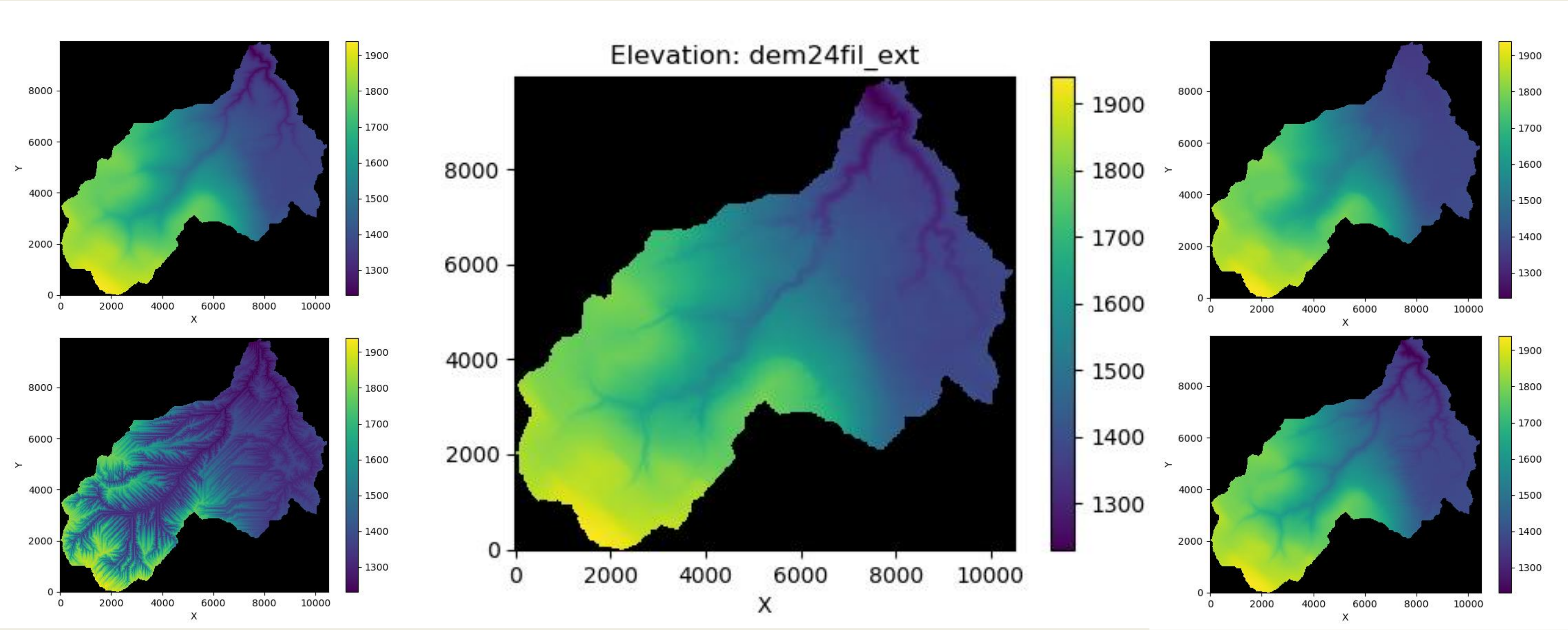
SOURCE: S. Bennett (2017) *Report of the West Valley Erosion Working Group Study 2: Recent Erosion and Deposition Processes*.

Sensitivity analysis shows low sensitivity to downcutting history or paleo-topography



EXAMPLE OF SENSITIVITY TO PARAMETERS, INITIAL CONDITIONS, AND LOWERING HISTORY FOR MODEL "BasicRt"

Models and parameters are tested by comparing observed and simulated modern topography



MODERN TOPOGRAPHY (CENTER) COMPARED WITH FOUR MODEL RUNS

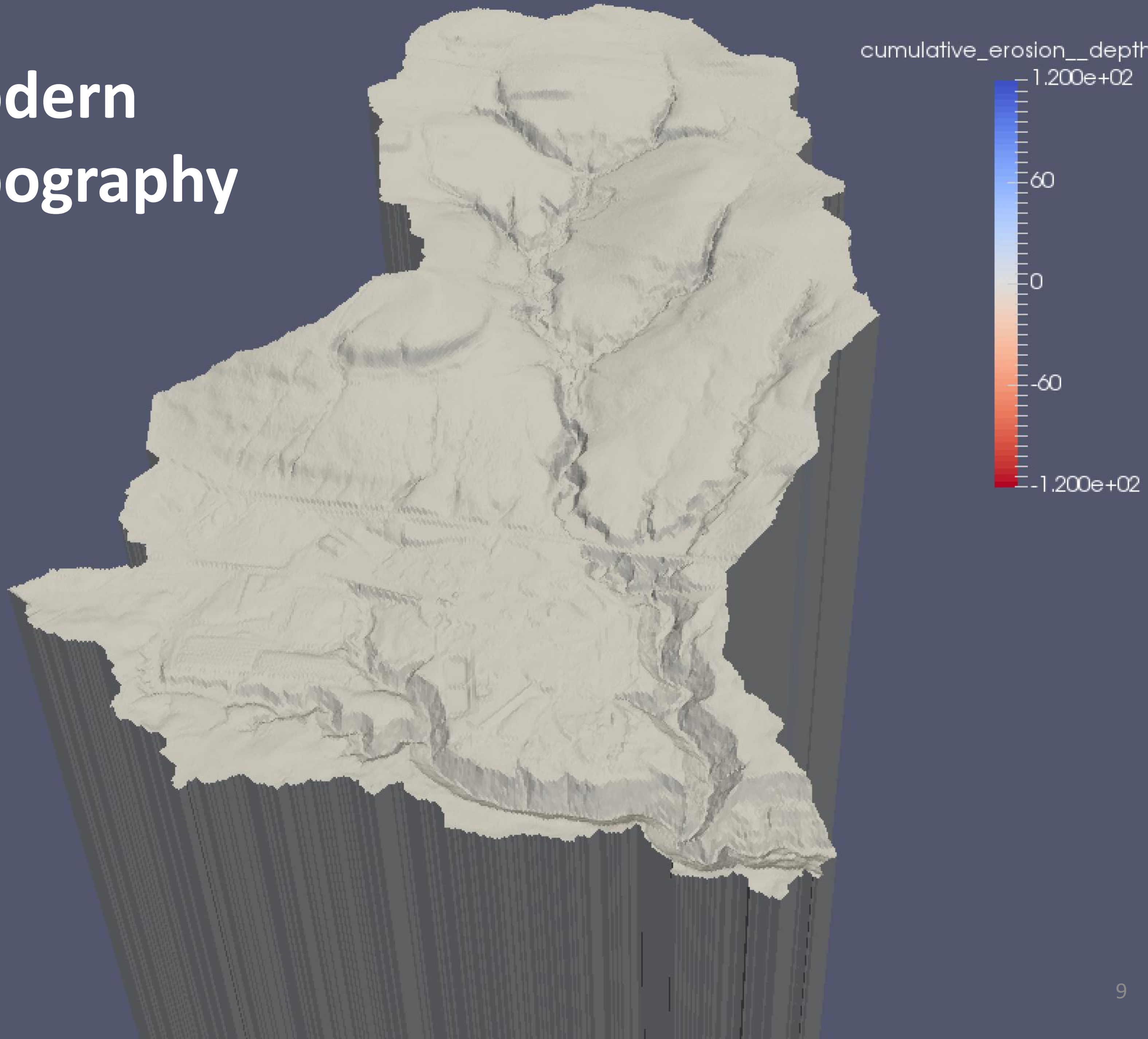
Calibration used to test and rank models and identify best parameters

- At least two possible reasons for a poor fit:
  1. Poor model
  2. Great model but wrong parameter choice

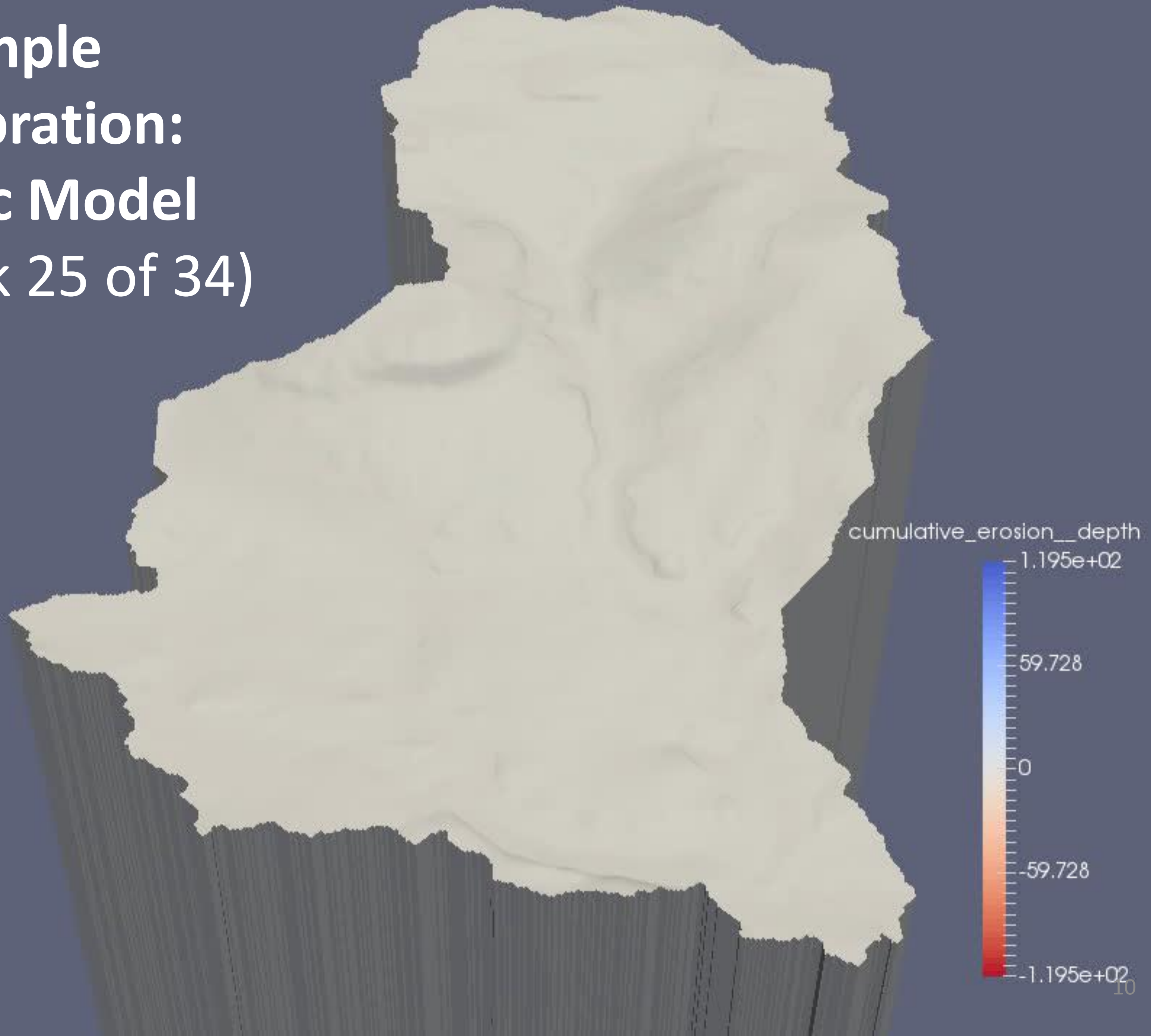
- Calibration provides:
  - Optimal parameter values
  - Measure of goodness of fit for each model

- Calibration performed on CU's **Summit** supercomputer
  - Project overall required over 1.3 million CPU hours
  - 34 of 37 successfully calibrated

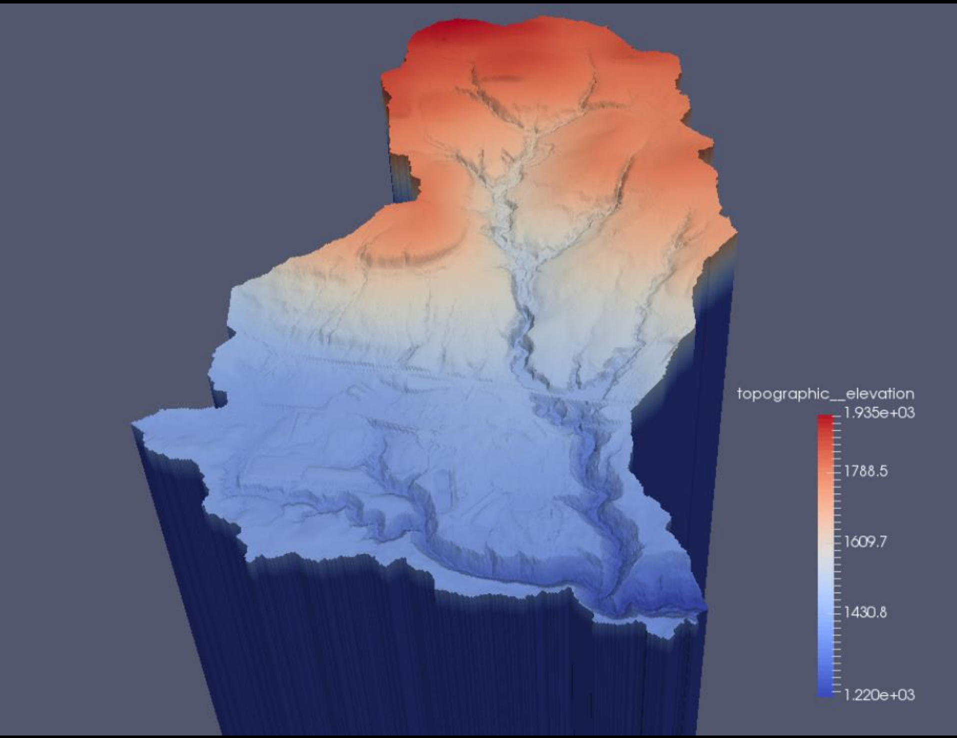
Modern topography



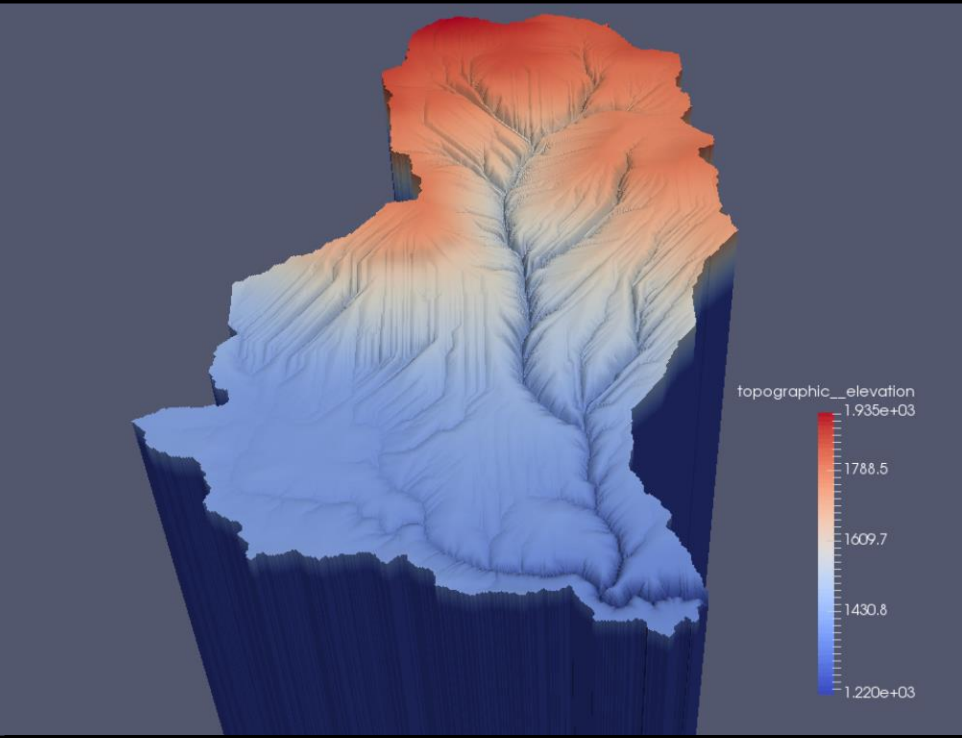
Example Calibration: Basic Model
(rank 25 of 34)



Observed versus modeled terrain: Basic model



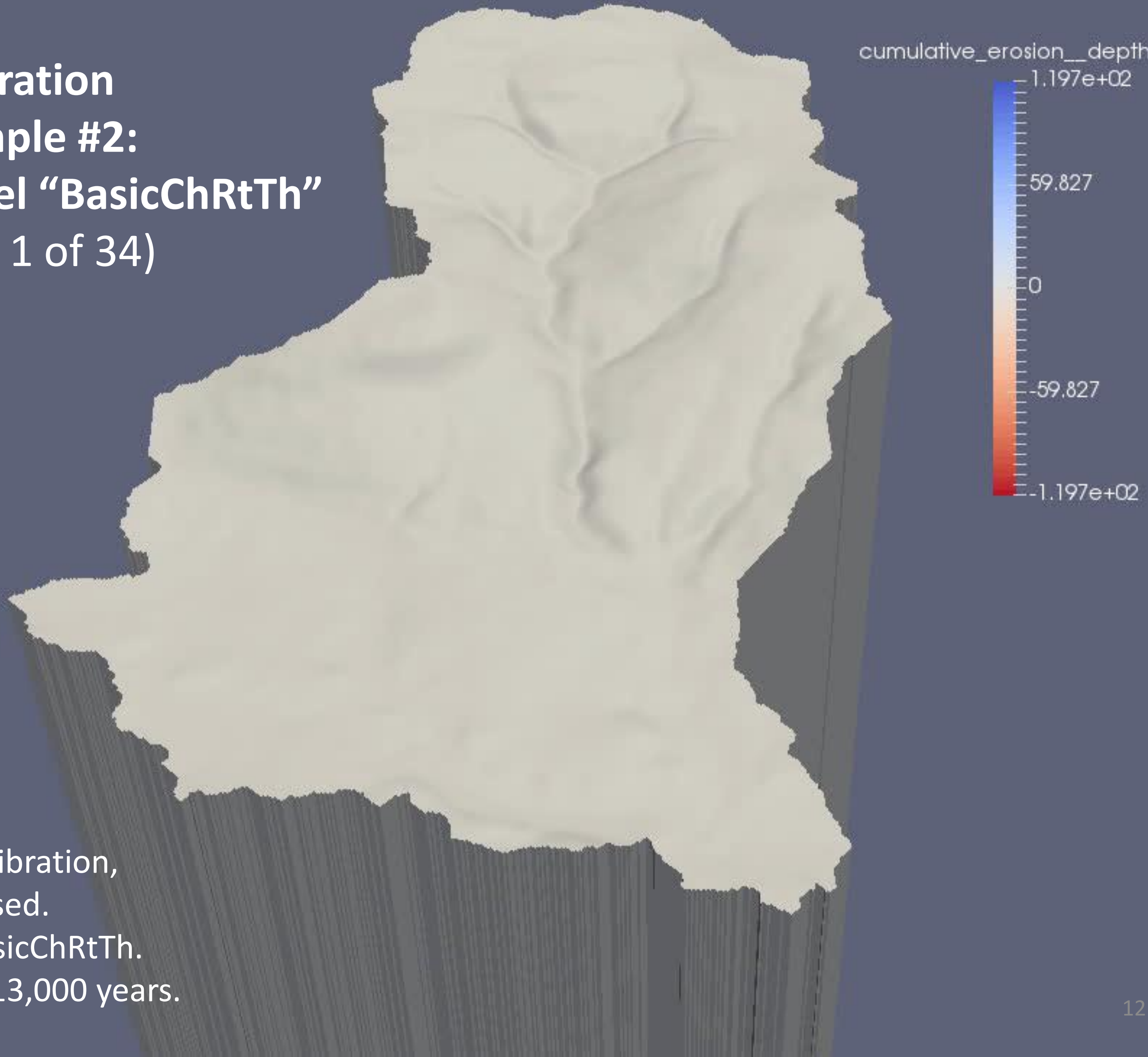
OBSERVED



BASIC MODEL (rank 25 of 34)

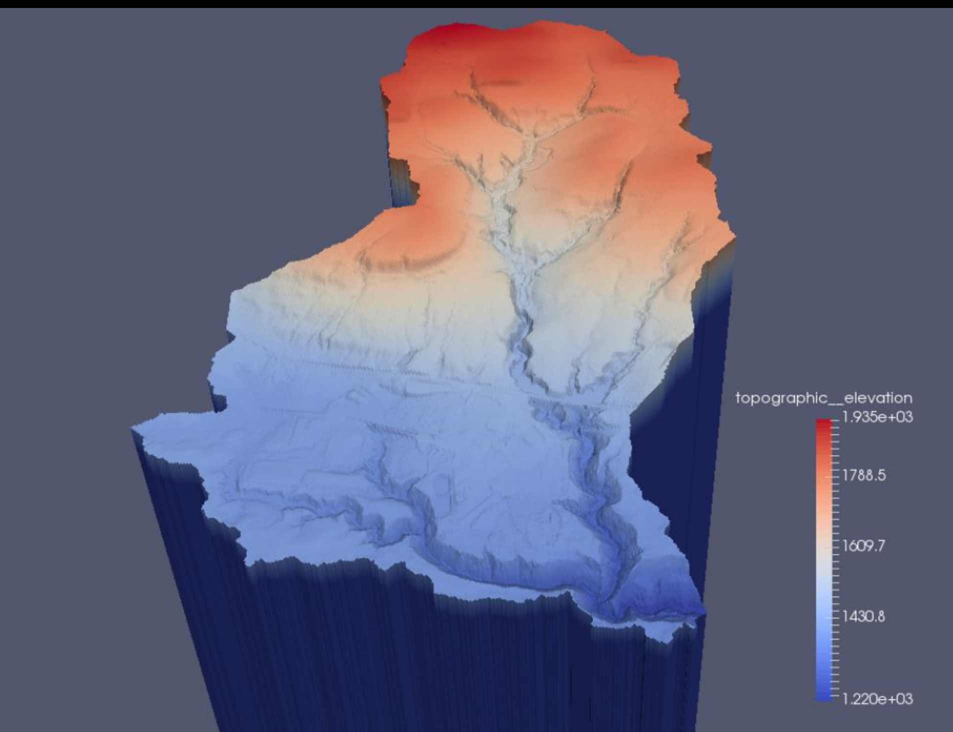
Calibration example #2: Model “BasicChRtTh”

(rank 1 of 34)

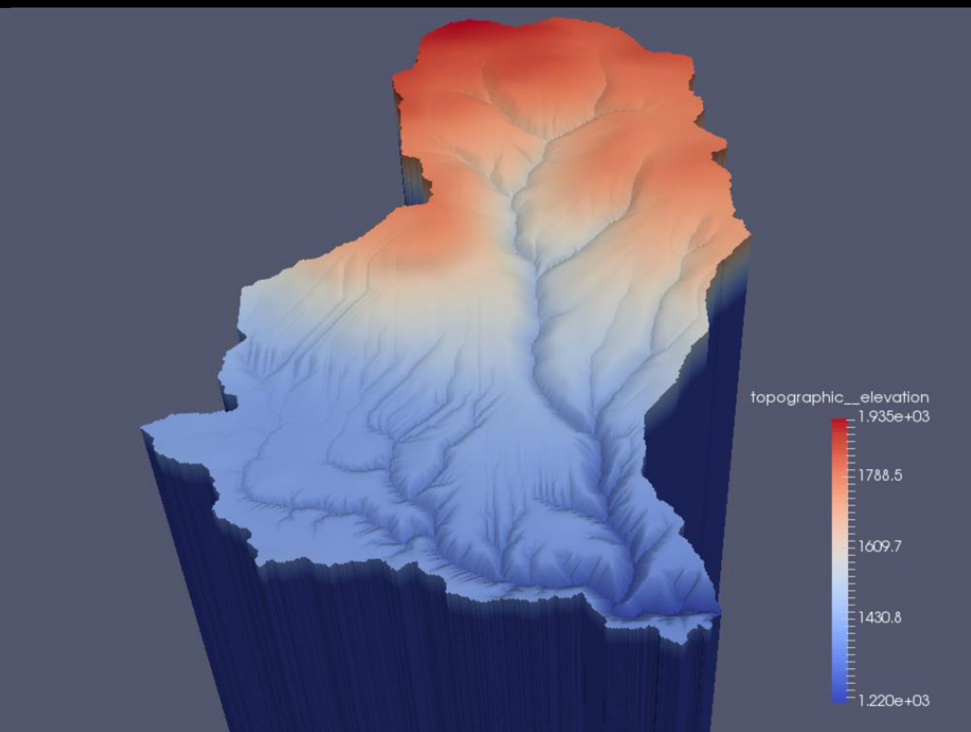


DRAFT calibration,
to be revised.
Model BasicChRtTh.
Duration 13,000 years.

Observed versus modeled terrain: Erosion threshold, nonlinear hillslope law, rock and till



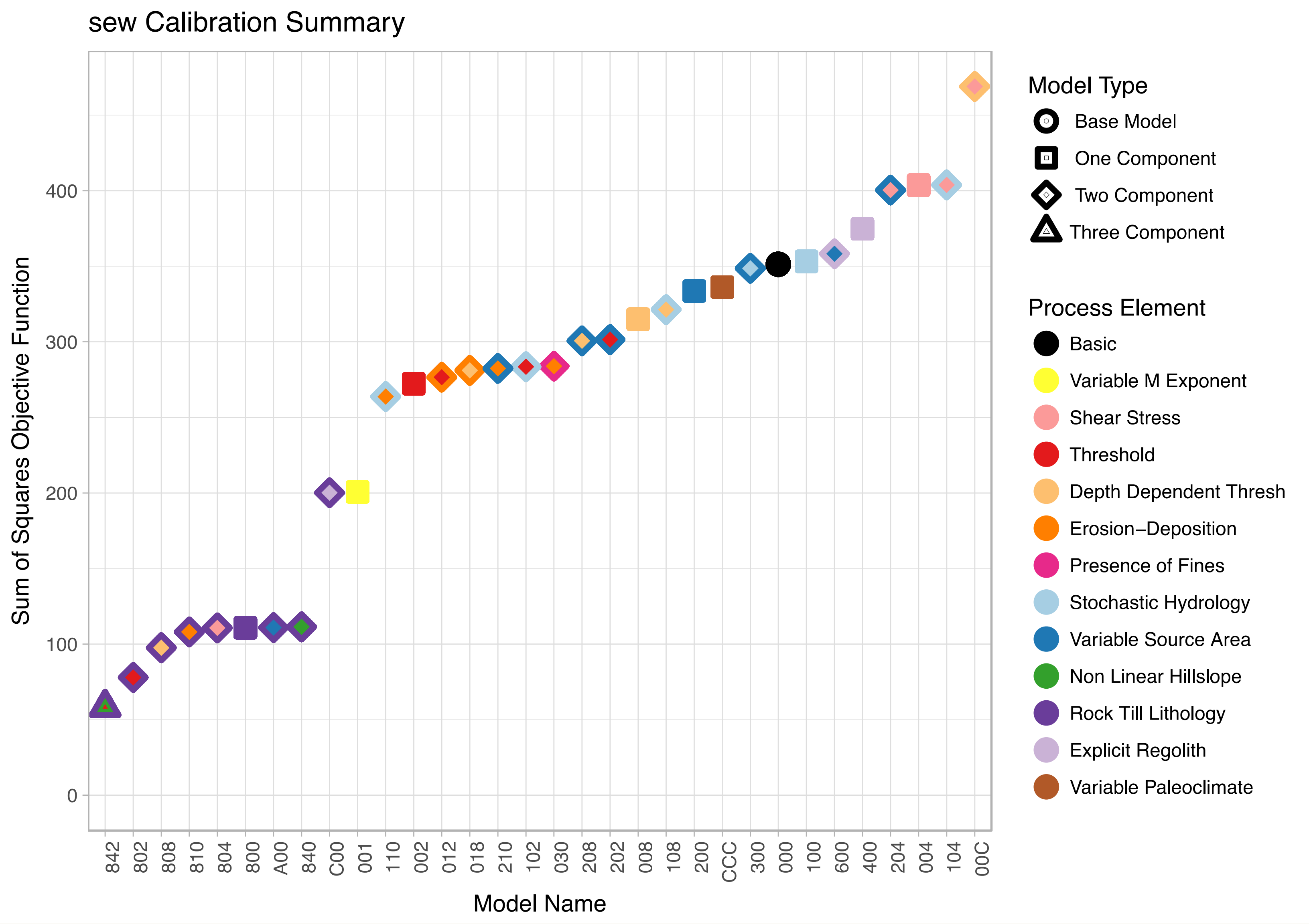
OBSERVED



BASIC MODEL
WITH EROSION THRESHOLD,
NONLINEAR HILLSLOPE LAW,
AND ROCK AND TILL UNITS
(rank 1 of 34)

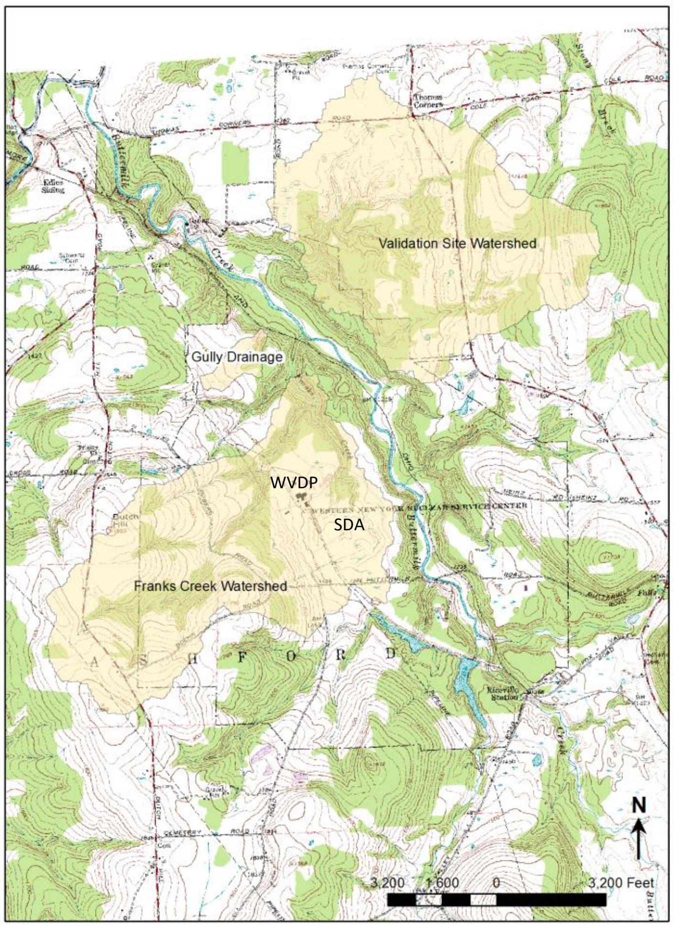
DRAFT calibration,
Model BasicChRtTh.
Duration 13,000 years.

SUMMARY OF CALIBRATION RESULTS

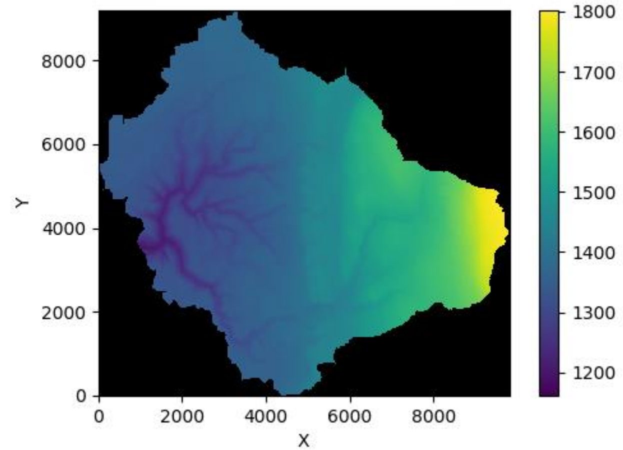


LOWER SCORE (VERTICAL AXIS) INDICATES A BETTER-PERFORMING MODEL

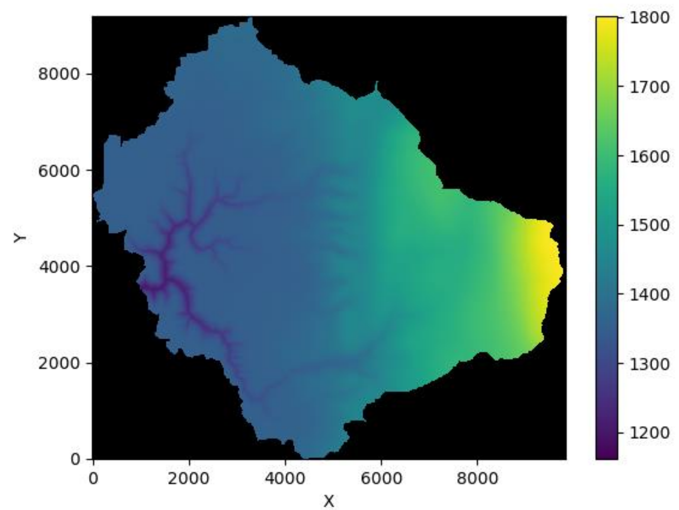
Models were validated by running on a nearby watershed of similar size and relief



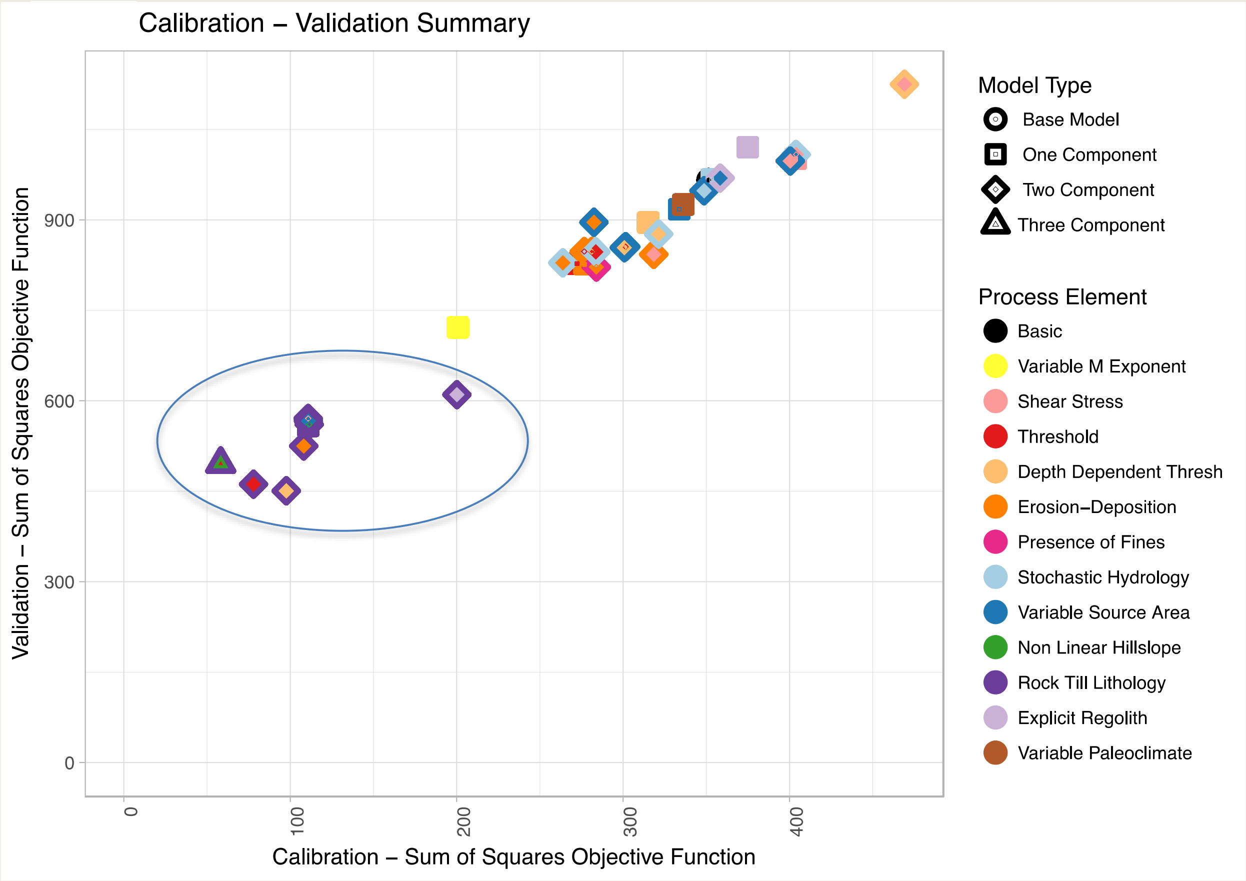
OBSERVED



SIMULATED



Models that performed well in calibration also performed well in validation tests



- Top 9 models in calibration and validation selected for erosion projection
- Top-performing models distinguish between glacial sediments & bedrock

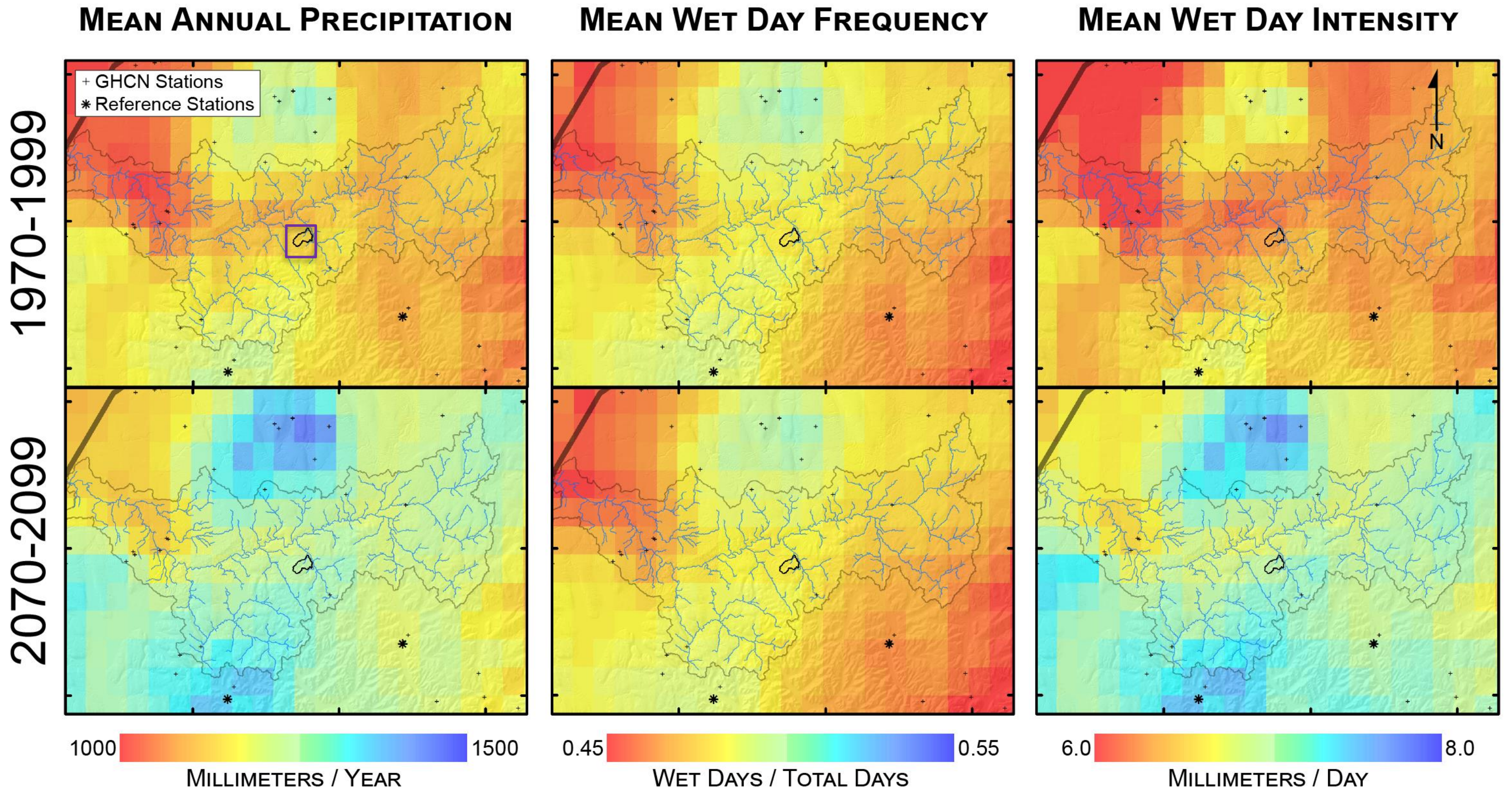
Future projections quantify uncertainty in five main areas:

- **Future climate:** run three alternative scenarios
- **Future downcutting on Buttermilk:** run three alternative scenarios
- **Terrain modification by humans:** run ensemble of simulations with random +/-5' elevation perturbations
- **Model structure:** run 9 different models
- **Model parameters:** propagate calibration uncertainty forward into prediction (seven models only due to compute time limits)

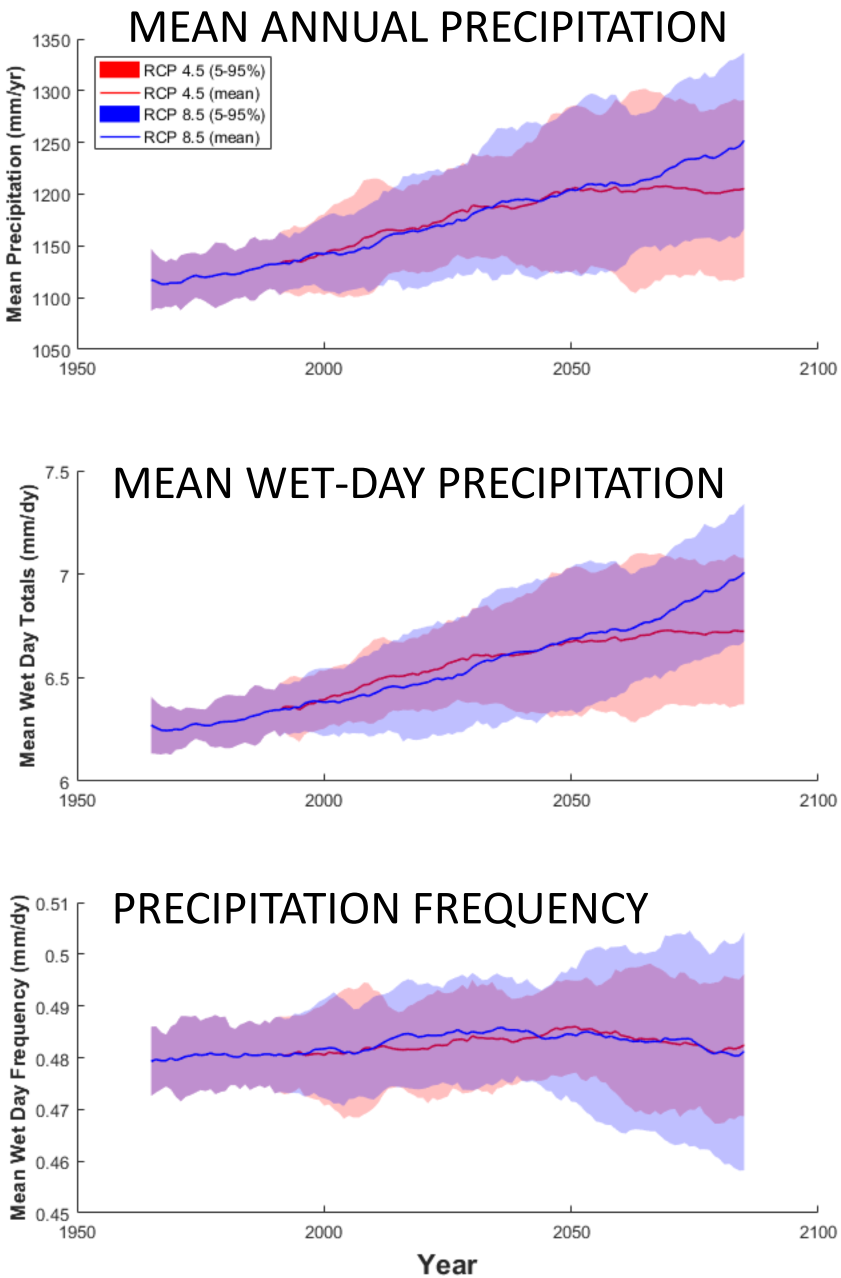
Sensitivity tests examine uncertainty from two additional sources:

- **Potential for upper Franks capture by gully:** run capture-from-southeast scenario
- **Potential for rapid Buttermilk widening:** run capture-from-east scenario

Scenarios for future climate were developed using MACA climate-model downscaling product



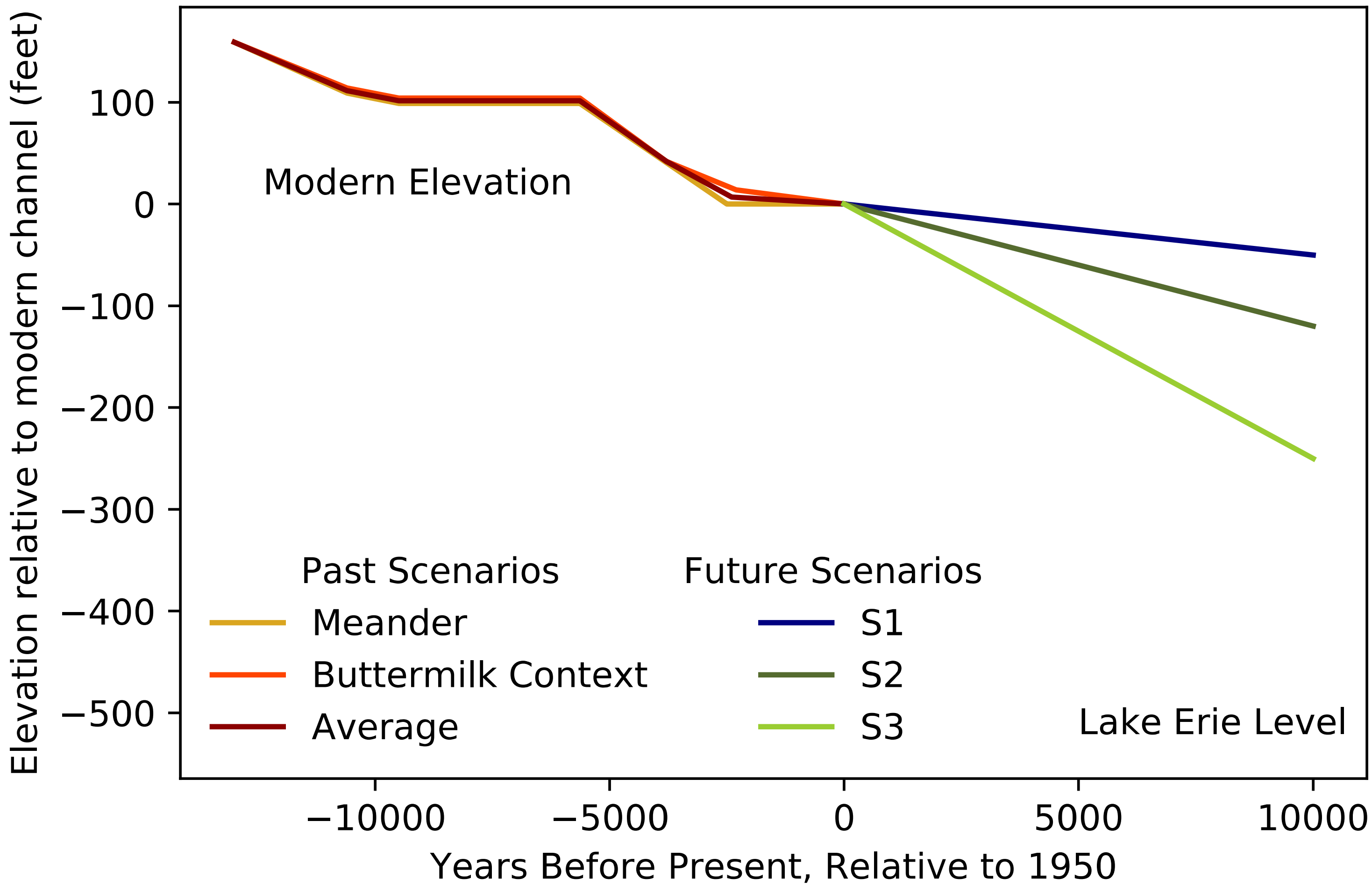
Data source: Multivariate Adaptive Constructed Analogs (MACA) Datasets
https://climate.northwestknowledge.net/MACA/



Three future climate scenarios

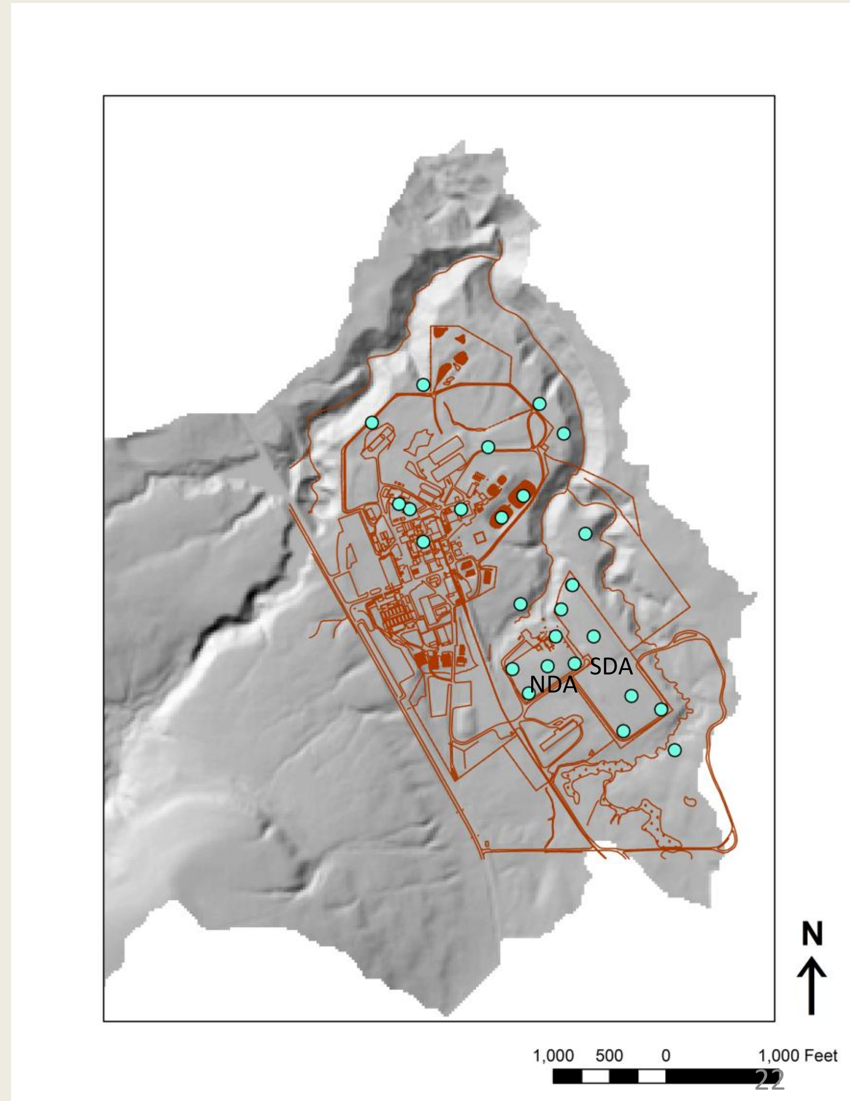
1. **Representative Concentration Pathway (RCP) 8.5: Increase mean wet day totals to 2100, then stabilize**
2. **Representative Concentration Pathway (RCP) 4.5: Increase mean wet day totals that level off by 2100**
3. **No change in mean wet day precipitation**

Three scenarios for future downcutting on Buttermilk Creek



Erosion projections plotted for 25 selected points at site

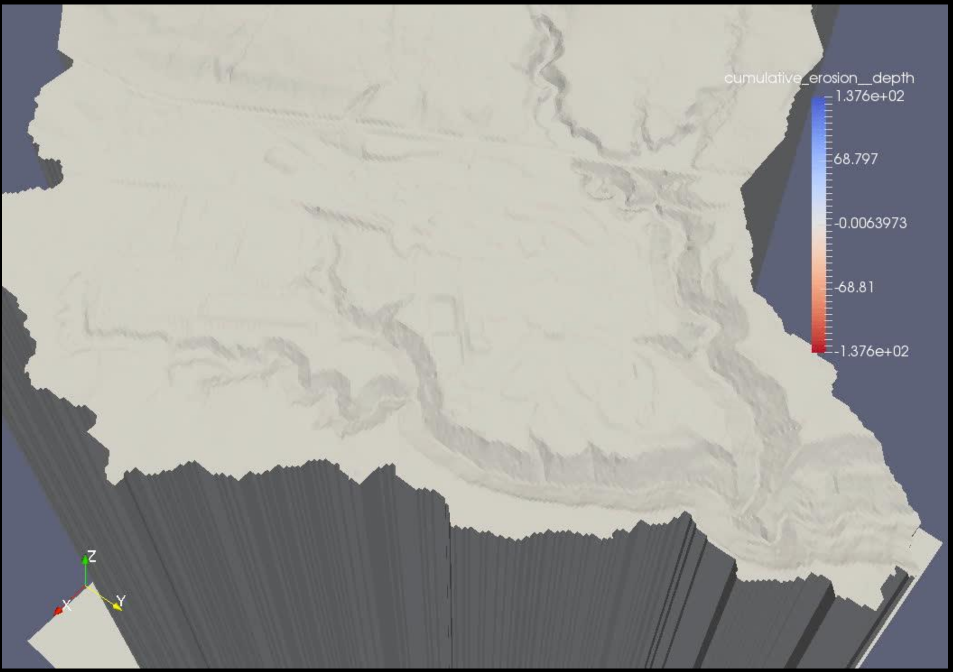
- Time intervals of 100 years
- All model and scenario projection runs store data for every grid location
- Parameter uncertainty runs focus only on the 25 points



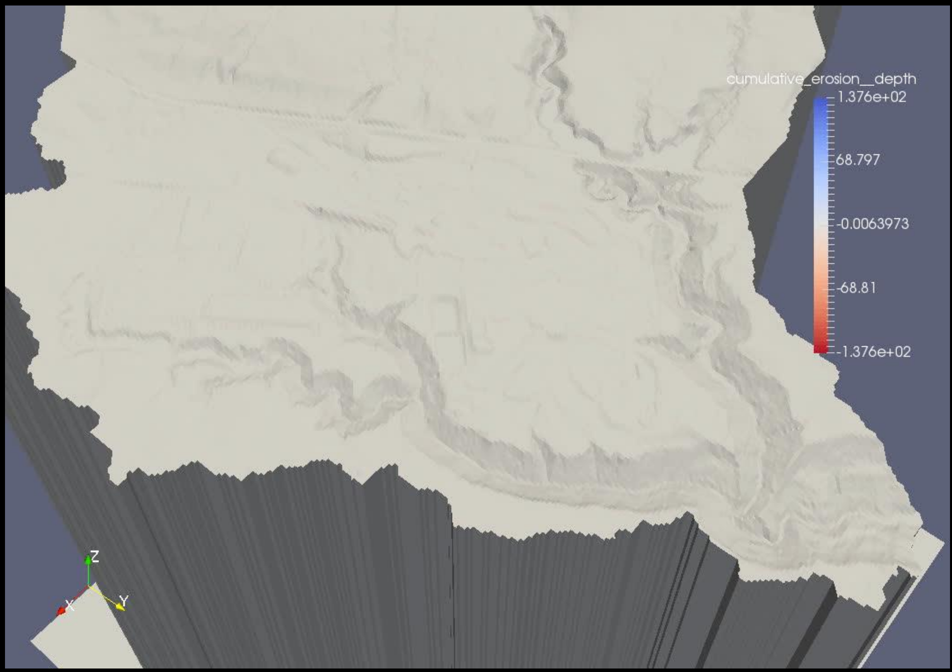
Dominant source(s) of uncertainty may vary from one location to another, and through time

- Sources include:
  - Unknown future climate
  - Unknown future rate of lowering in surrounding areas
  - Small variations or perturbations in topography
  - Parameters in erosion models
  - Model structure
- Side-by-side comparison of projections with two different models illustrates model structure uncertainty

Example of model structure uncertainty

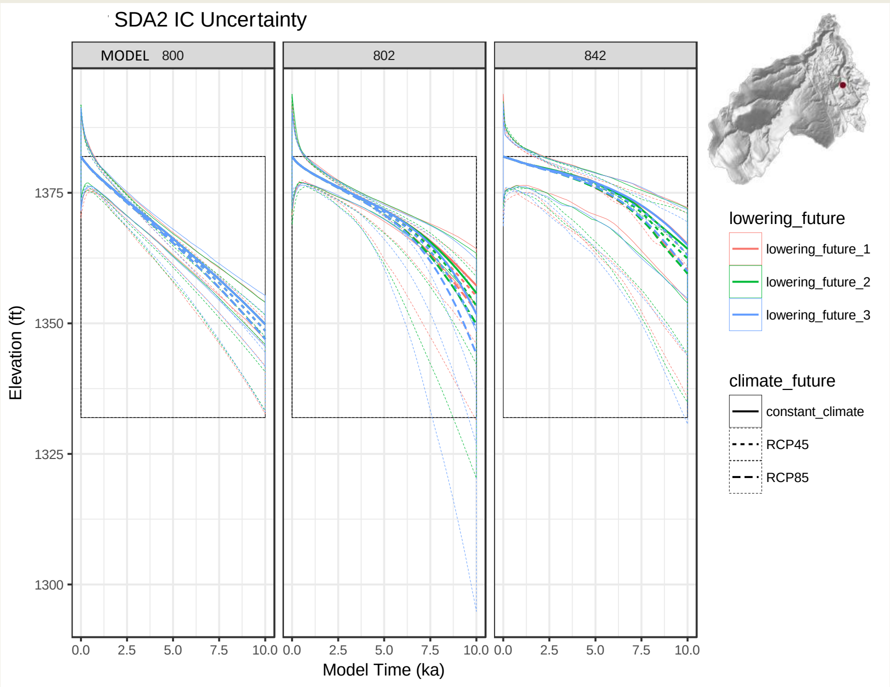


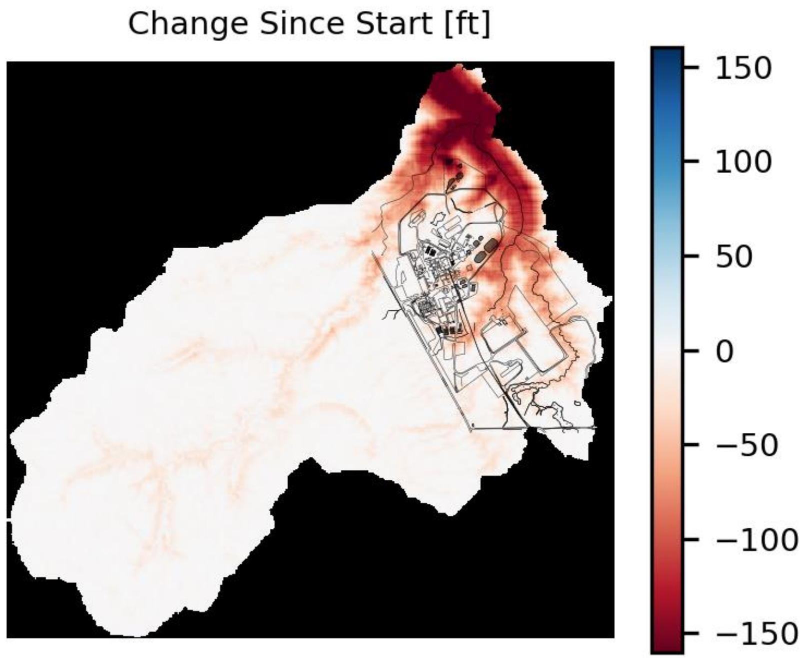
MODEL "BasicRt"
10,000-year run
Lowering scenario 2

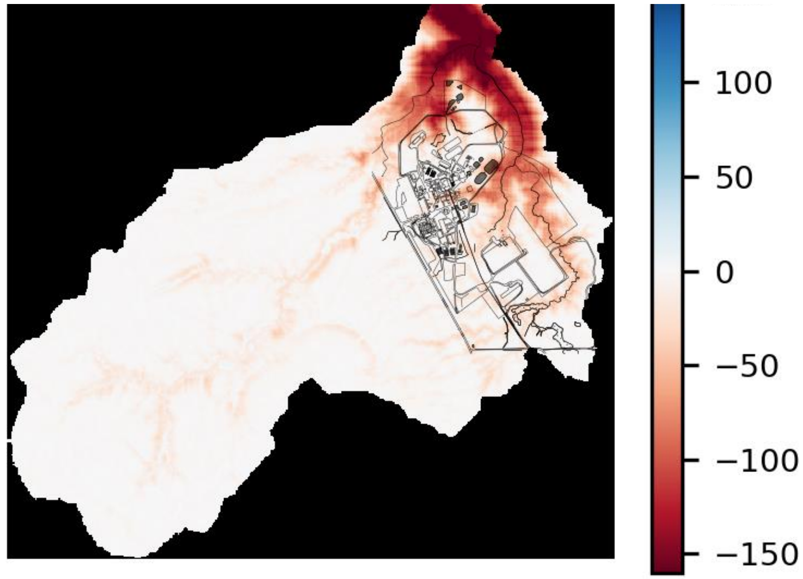


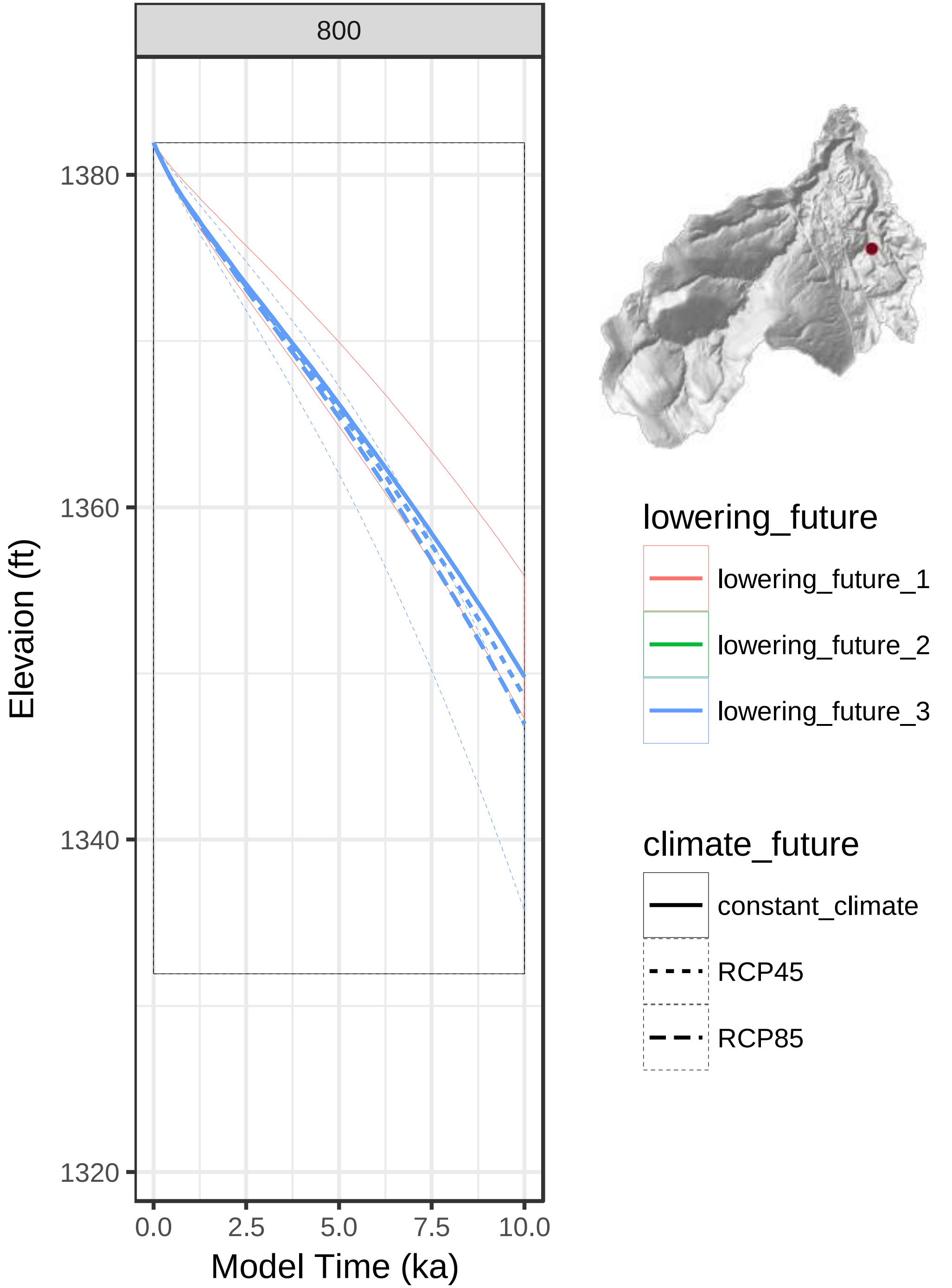
MODEL "BasicChRtTh"
10,000-year run
Lowering scenario 2

Example of uncertainty in initial topography (representing human modification of landscape)

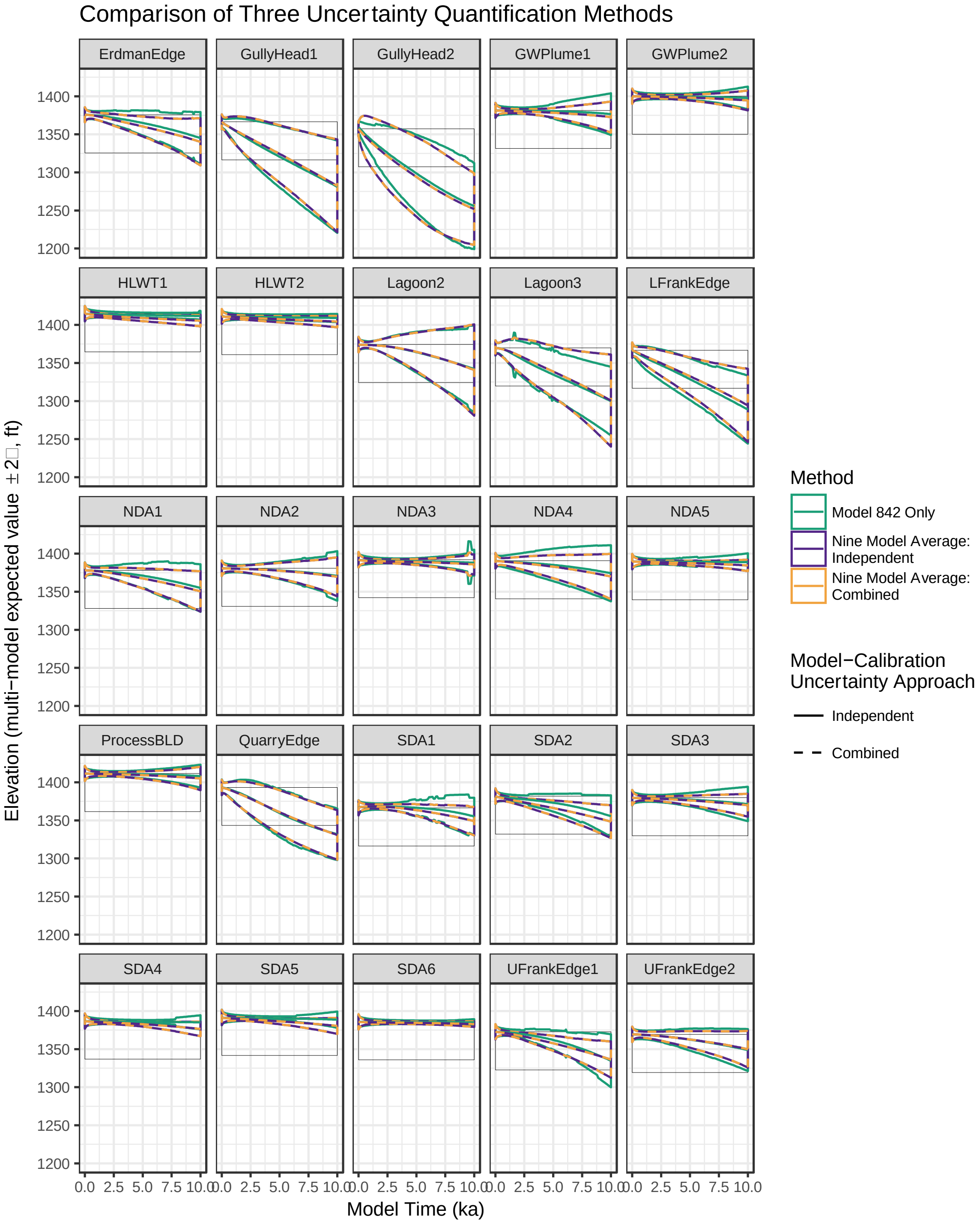




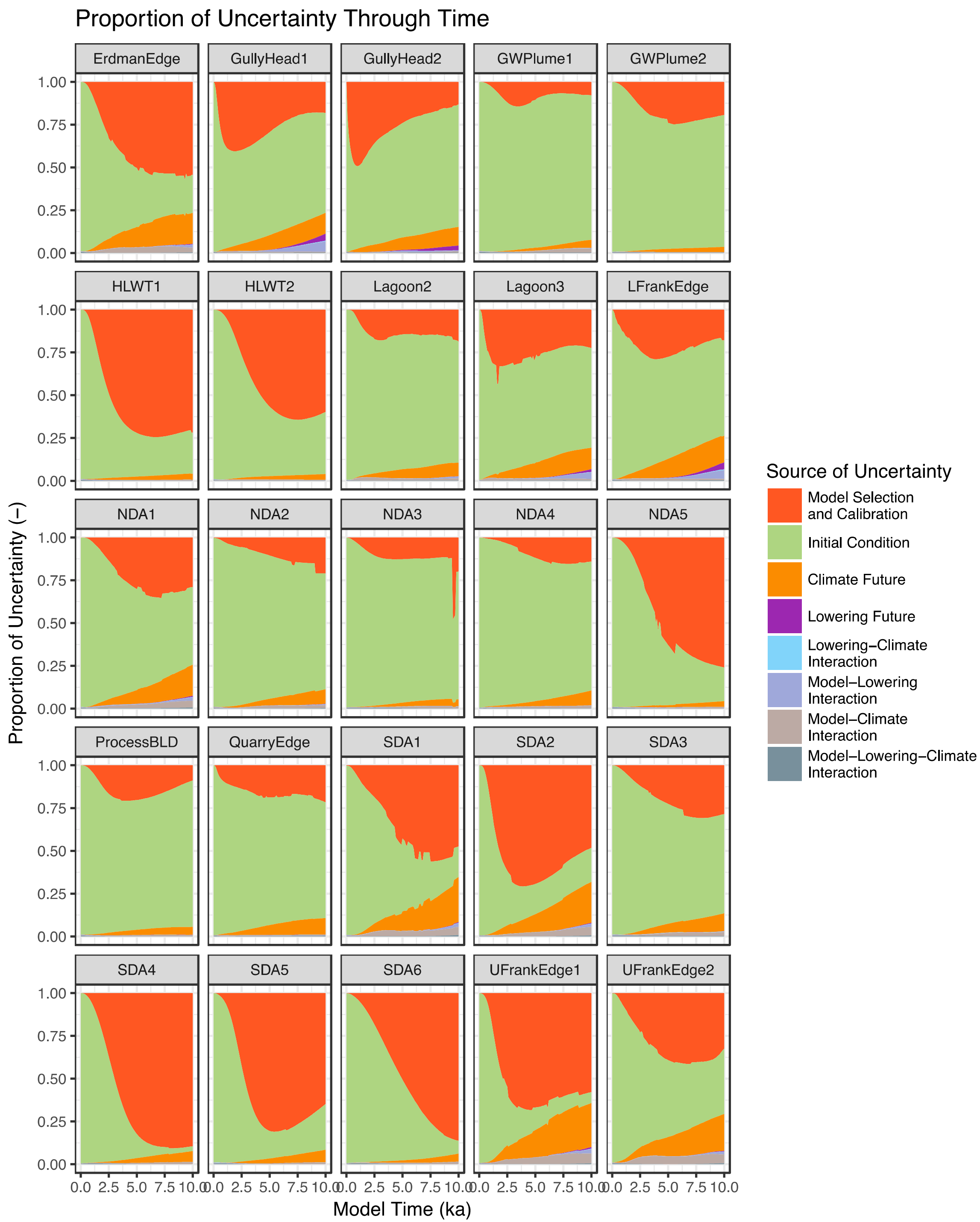




Example of erosion projections at a point, with uncertainty arising from **parameter value uncertainty**



At-a-point predictions with uncertainty bounds, combining all quantified uncertainty sources

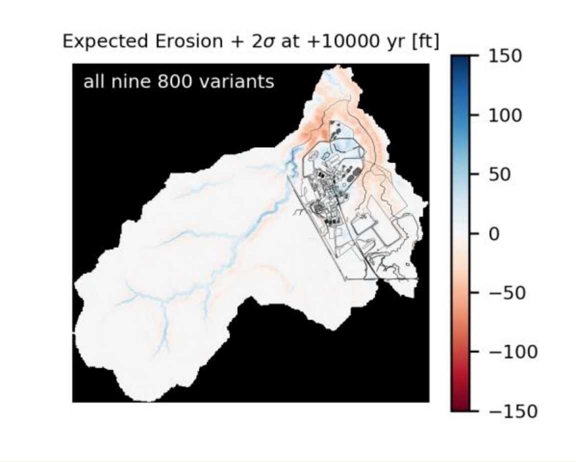


Relative contributions of different sources of uncertainty, by location and time

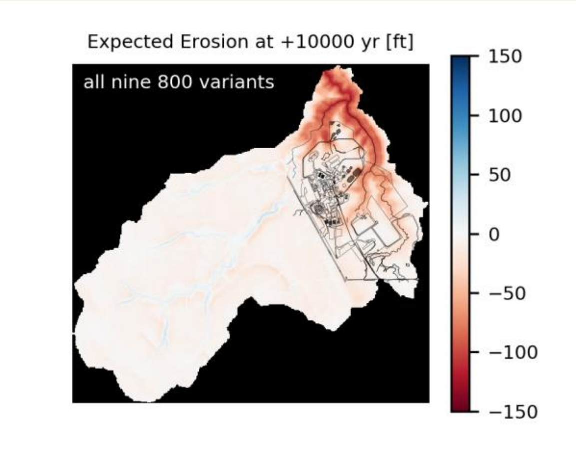
Example of ensemble-based projected erosion maps

9-MODEL COMPOSITE

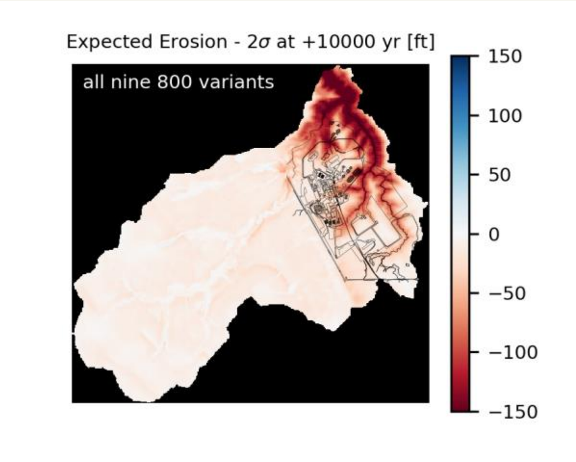
LOWER 95% PERCENTILE

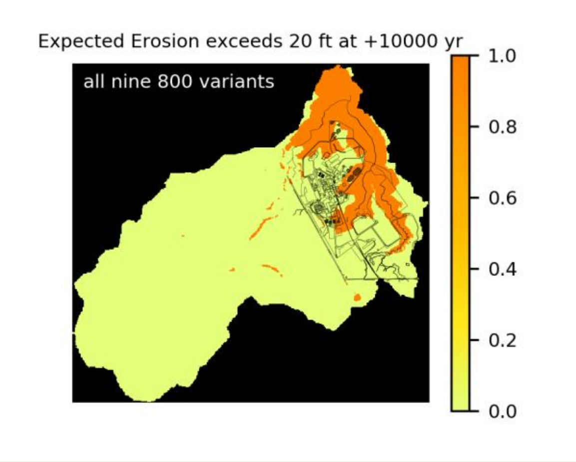


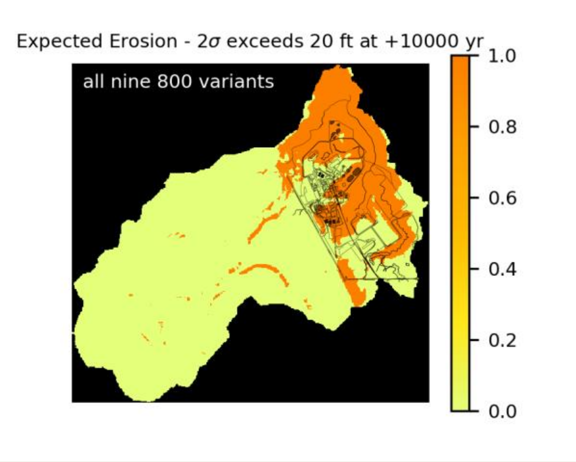
EXPECTED EROSION



UPPER 95% PERCENTILE







Summary of uncertainty results

- Major sources of uncertainty in future erosion estimates include:
  - Initial topography / human modification of landscape
  - Model structure
  - Model parameters

  } = Model selection and calibration
- Other sources are:
  - Climate
  - Downcutting in Buttermilk valley
- Degree of uncertainty and relative importance of different sources varies among locations

Erosion modeling provides information for further erosion assessment:

- Calculations of potential future erosion at each model grid cell
- Calculations include quantitative estimates of uncertainty in model structure, future climate, initial topography, and future Buttermilk Creek downcutting
- Estimates of uncertainty arising from model parameters are provided 7 models at 25 selected points
  - Workflow and codes available to perform calculations for other models and/or locations
- Scenarios also calculated for potential capture of upper Franks Creek by gully erosion to the southeast or Buttermilk valley widening near Heinz Creek fan
- Process model results provide basis for probabilistic modeling of erosion using multiple alternative scenarios

QUESTIONS?