# Exploring river response to tectonic perturbations with the open source, 2-D SPACE model

Charles M. Shobe (charles.shobe@colorado.edu), Gregory E. Tucker, and Katherine R. Barnhart
CIRES and Department of Geological Sciences, University of Colorado

## SPACE is a new, freely available numerical model

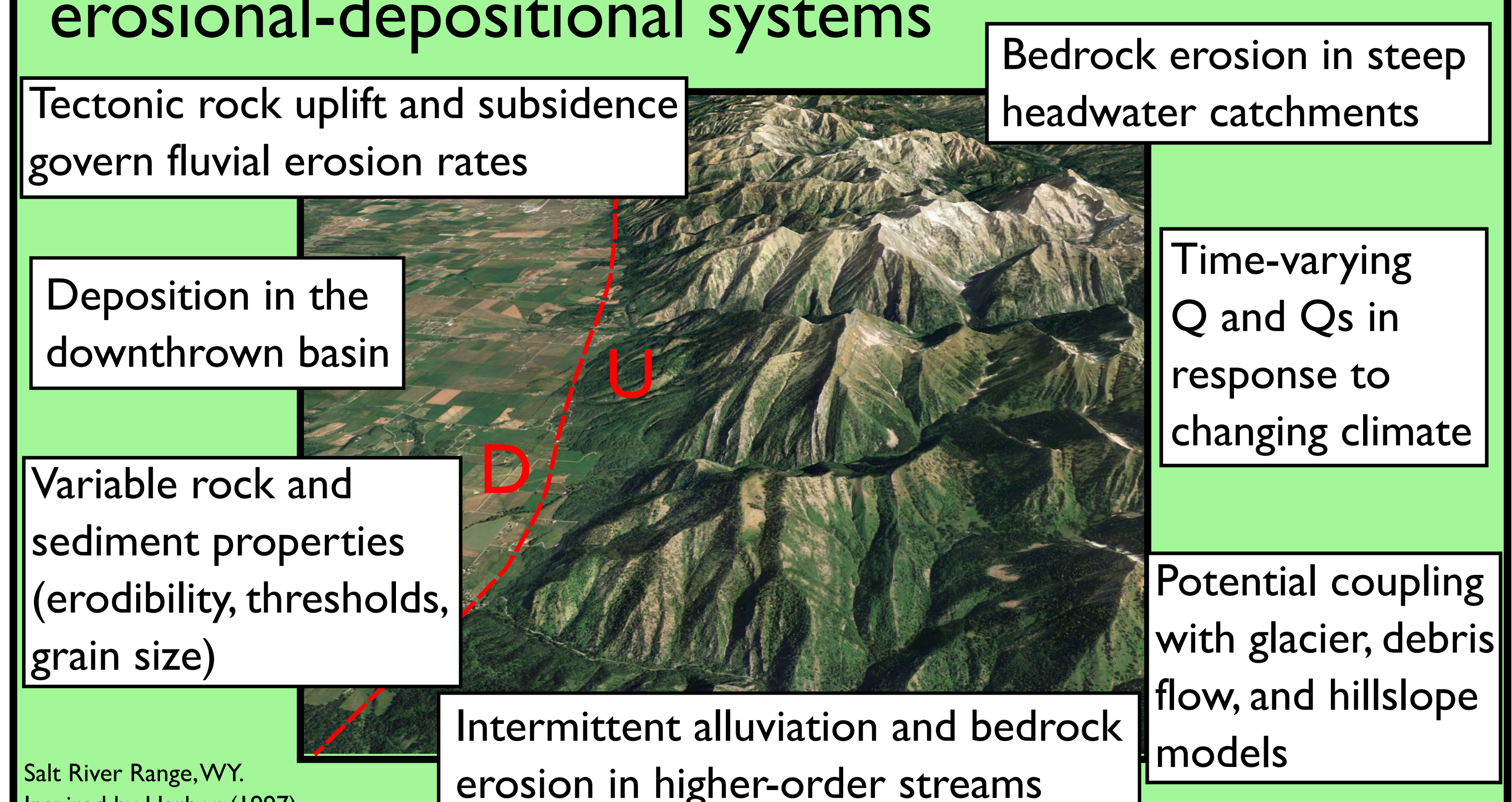
SPACE stands for **S**tream **P**ower with **A**lluvium **C**onservation and **E**ntrainment, and is a new model for computing sediment transport, bedrock erosion, and landscape evolution over large spatial and temporal scales.

SPACE expands the erosion-deposition style model of Davy and Lague (2009) to encompass simultaneous erosion of sediment and bedrock. The key advance of SPACE over other stream-power-based bedrock erosion models is that SPACE tracks the conversion of bedrock to sediment as well as the erosion and deposition of sediment, making it useful for modeling systems in which both bedrock erosion and sediment transport play important roles.

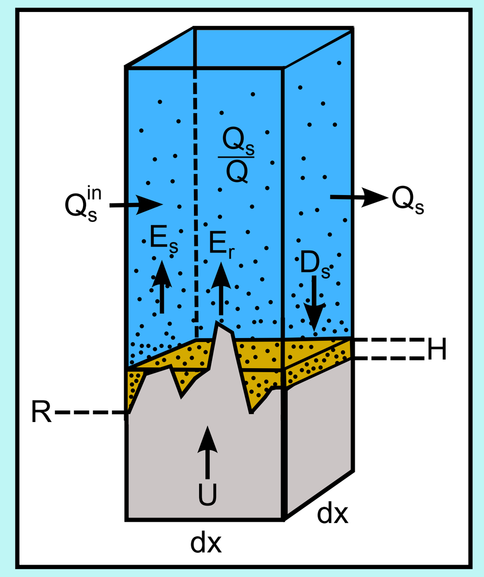
For example, bedrock-alluvial channels, as well as channels with bedrock headwaters and alluviated lower reaches, are ubiquitous. SPACE is one of few models (in addition to those of Lague (2010) and Zhang et al (2015)) equipped to model such systems from source to sink.

SPACE is able to:
1. model simultaneous bedrock erosion and sediment transport
2. transition smoothly between detachment-limited, transport-limited, and mixed behavior
3. operate in two dimensions at the landscape scale
4. be coupled with other tectonic and surface process models as a component of the Landlab modeling toolkit.

## SPACE can model tectonic influences on coupled erosional-depositional systems



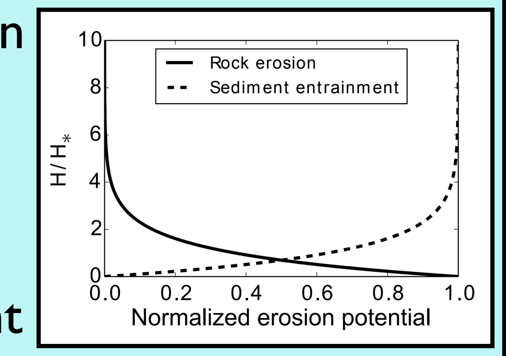

## How does SPACE work?



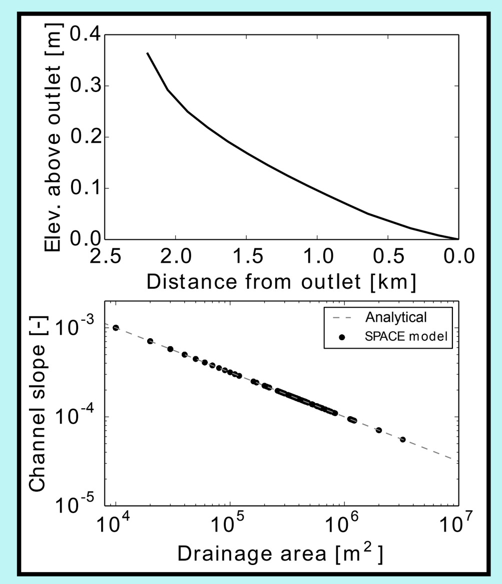

SPACE simultaneously conserves sediment in the water column, sediment on the bed, and bedrock.

Sediment entrainment is a function of stream power and sediment availability (thickness).

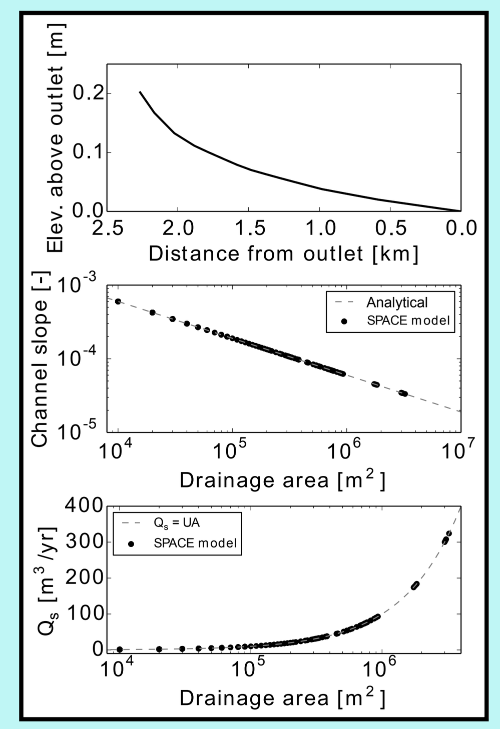
Rock erosion depends on stream power and is inhibited by sediment cover.



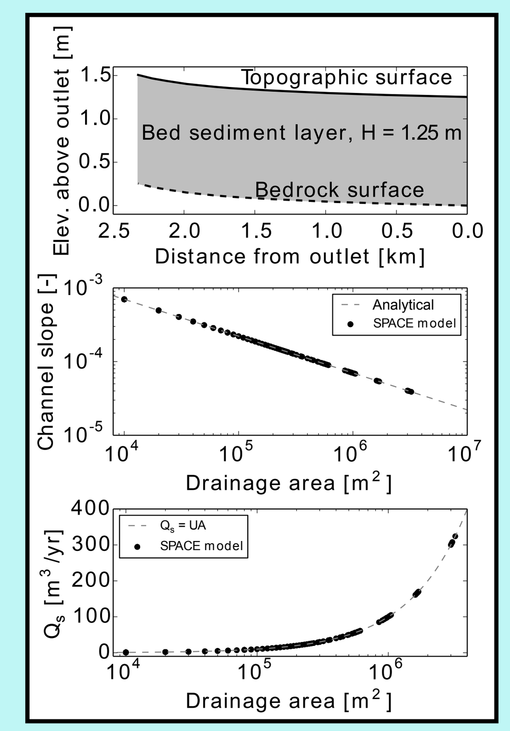

## Comparison with steady analytical solutions




Detachment-limited case: No sediment, all eroded bedrock is passed out of the model domain. Steady-state channel profile has constant concavity; slope-area plot shows predicted power-law scaling.



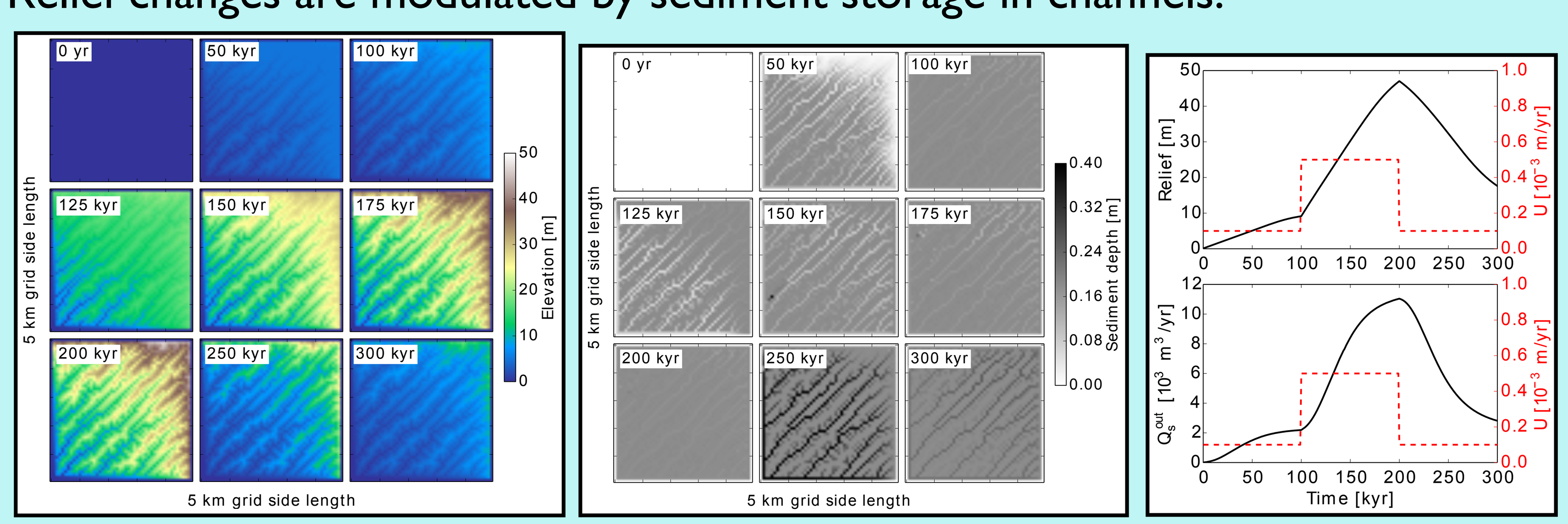

Transport-limited case: No bedrock exposed. Steady-state channel profile has constant concavity; slope-area plot shows power-law scaling; sediment flux is the product of drainage area and uplift rate.



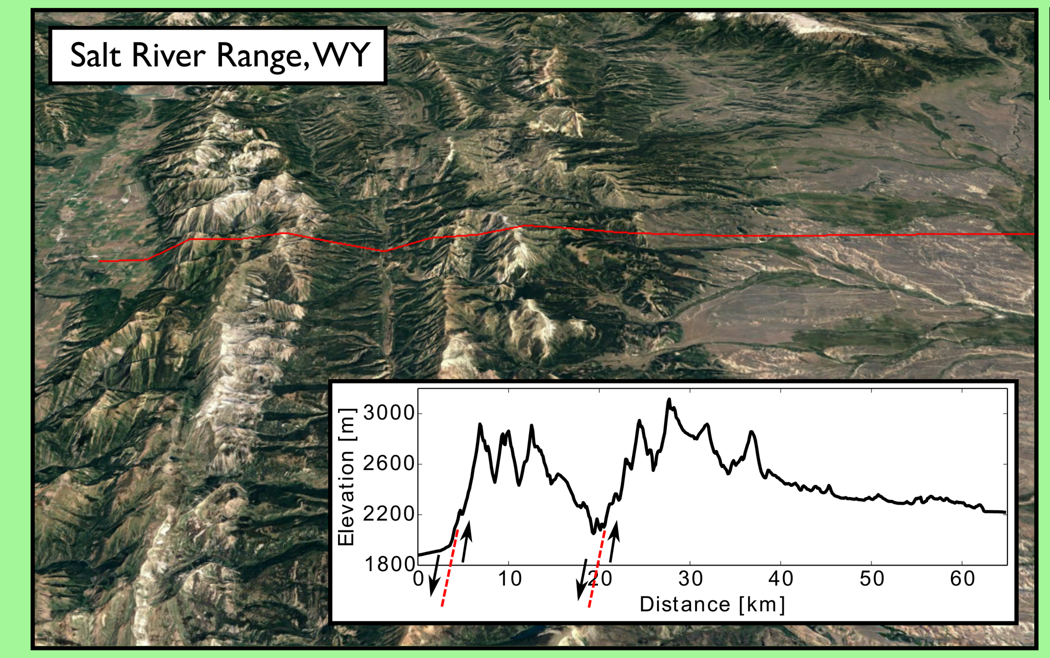

Mixed bedrock-alluvial case: Sediment layer of uniform thickness develops; steady-state channel profile has constant concavity; slope-area plot and sediment flux match analytical predictions.

## Application: Topographic growth and decay

Temporally variable rock uplift (red line) causes growth and decay of relief. Relief changes are modulated by sediment storage in channels.



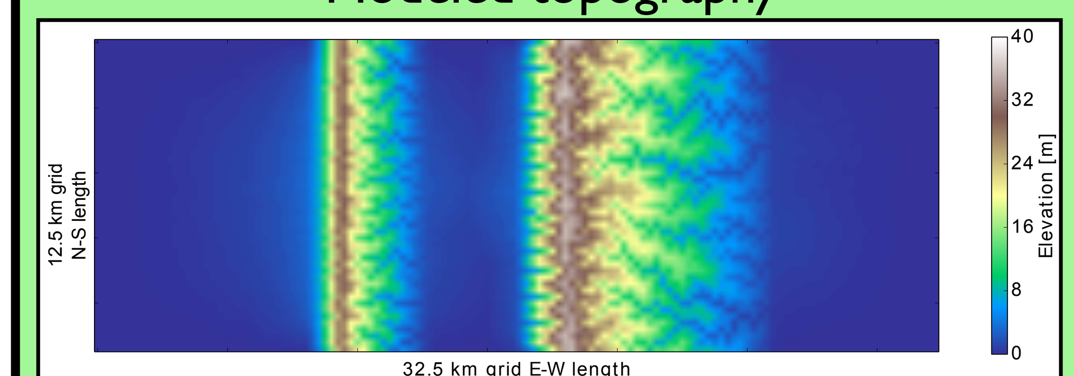

## Application: Basin and Range landscape evolution



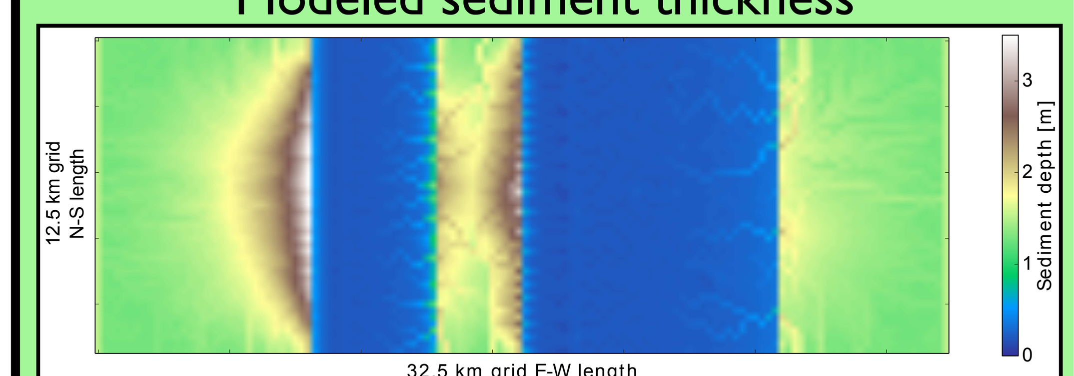


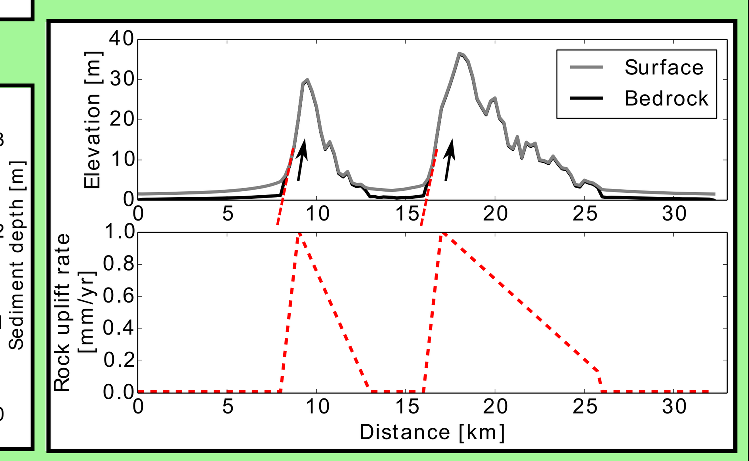
Coupling SPACE with Landlab components for soil production and depth-dependent hillslope diffusion, our model re-creates many features of basin and range landscape evolution noted by Harbor (1997), including divide migration, sediment accumulation at the base of the 'scarp domains,' alluviated channels on the 'flank domains,' and sedimentation of downthrown regions.

Modeled topography




Modeled sediment thickness




## Find the SPACE description paper and code:

Model description paper in *Geoscientific Model Development:*
https://doi.org/10.5194/gmd-2017-175

Landlab code base including SPACE source code:
http://landlab.github.io/

References and acknowledgements:

Davy, P. and D. Lague (2009), Fluvial erosion/transport equation of landscape evolution models revisited, *J. Geophys. Res.*

Harbor, D.J. (1997), Landscape evolution at the margin of the Basin and Range, *Geology*.

Lague, D. (2010), Reduction of long-term bedrock incision efficiency by short-term alluvial cover intermittency, *J. Geophys. Res.*

Shobe, C.M., G.E. Tucker, and K.R. Barnhart (in revision), The SPACE 1.0 model: A Landlab component for 2-D calculation of sediment transport, bedrock erosion, and landscape evolution, *Geosci. Mod. Dev.*

Zhang, L., G. Parker, C.P. Stark, T. Inoue, E. Viparelli, X. Fu, and N. Izumi (2015), Macro-roughness model of bedrock-alluvial river morphodynamics, *Earth Surf. Dyn.*

Thanks to NSF ACI-1147454 and ACI-1450409, as well as J. Adams, A. Carriere, R. Glade, H. Gray, S. Harbert, A. Hurst, K. Kochanski, R. van Balen, C. Le Bouteiller, and M. Rossi.