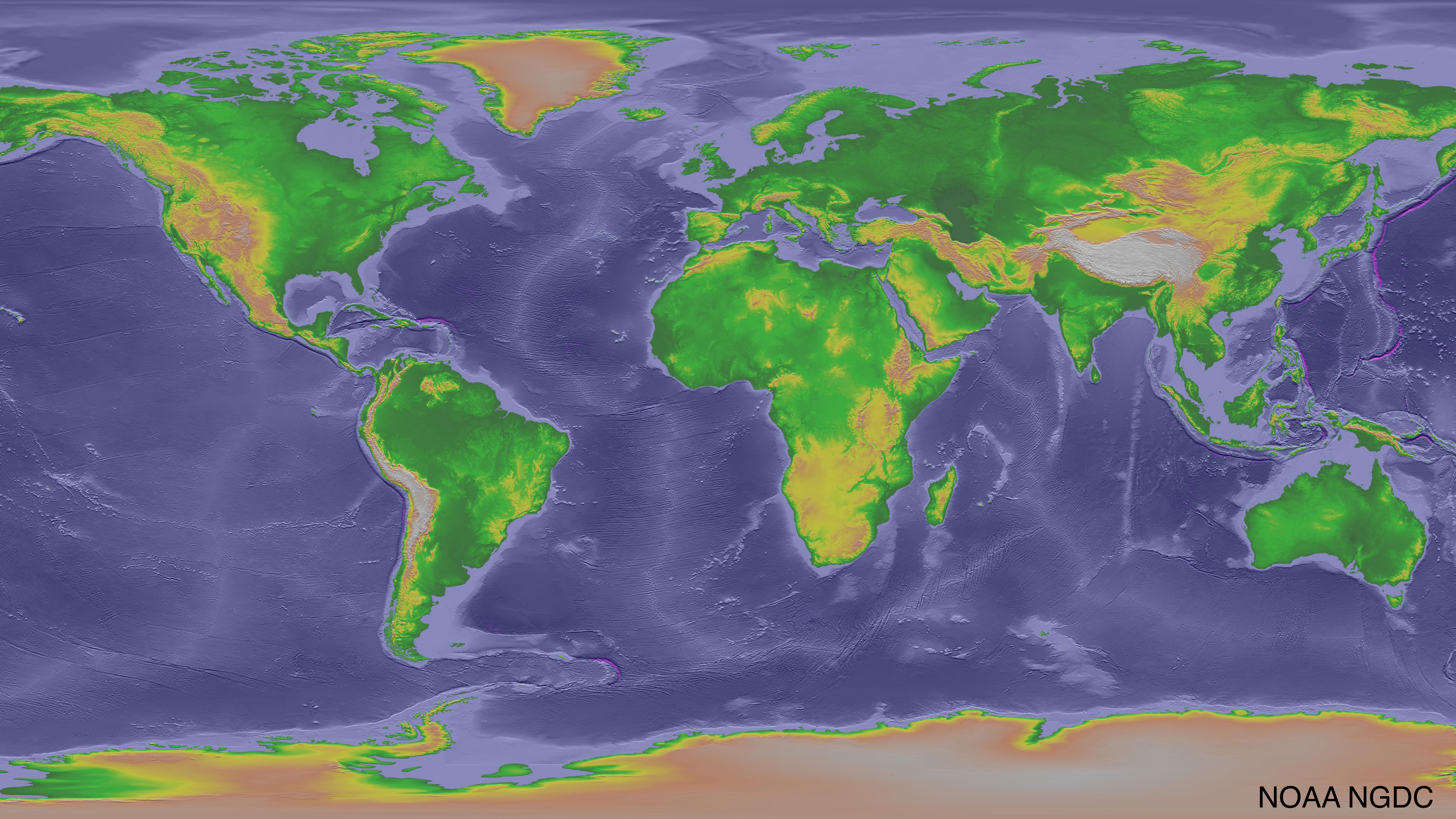
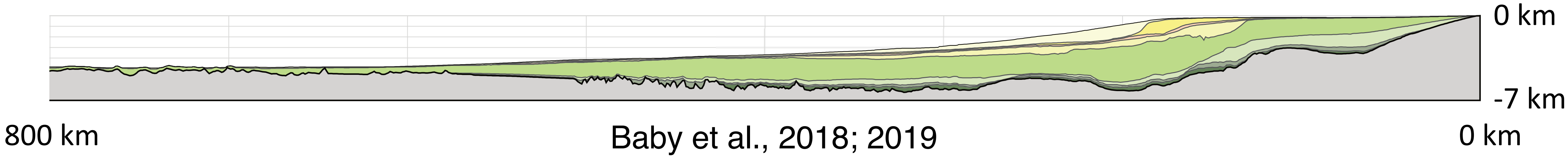
Refining predictive models for passive margin stratigraphy by inverting the sedimentary record

Charlie **Shobe**, GFZ Potsdam and West Virginia U.
Jean **Braun**, GFZ Potsdam
Xiaoping **Yuan**, GFZ Potsdam
Benjamin **Campforts**, CU Boulder
Guillaume **Baby**, Géosciences Rennes
François **Guillocheau**, Géosciences Rennes
Cécile **Robin**, Géosciences Rennes

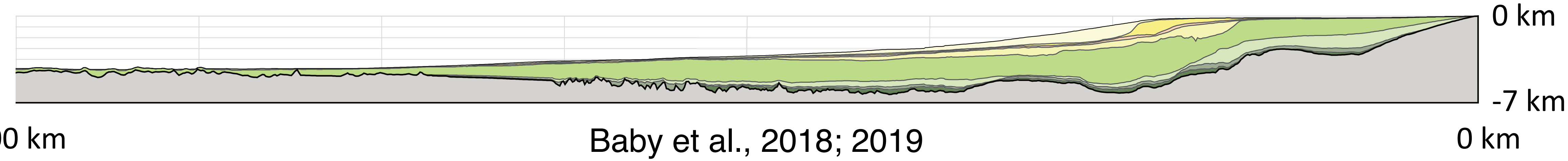

NOAA NGDC

How can we **simply and accurately** predict the development of passive margin stratigraphy **over geologic time** (>100 Ma)?

How do we determine **optimal model structure and parameter values**?



0 km
-7 km
800 km
Baby et al., 2018; 2019
0 km



Baby et al., 2018; 2019

How can we:

1) Transport sediment over **vanishingly low slopes**? and

2) Acknowledge a **slope of non-deposition**?

Topographic change

Flux imbalance

$$\frac{\partial \eta}{\partial t} = -\frac{\partial q_s}{\partial x} = -E + D$$

Sediment entrainment rate

Sediment deposition rate

Topographic change

Flux imbalance

$$\frac{\partial \eta}{\partial t} = -\frac{\partial q_s}{\partial x} = -E + D$$

Sediment entrainment rate

Sediment deposition rate

Linear function of local slope, declines exponentially with water depth

Steckler et al., 1993
Paola, 2000
Carretier et al., 2016
Ding et al., 2019

Topographic change

Flux imbalance

$$\frac{\partial \eta}{\partial t} = -\frac{\partial q_s}{\partial x} = -E + D$$

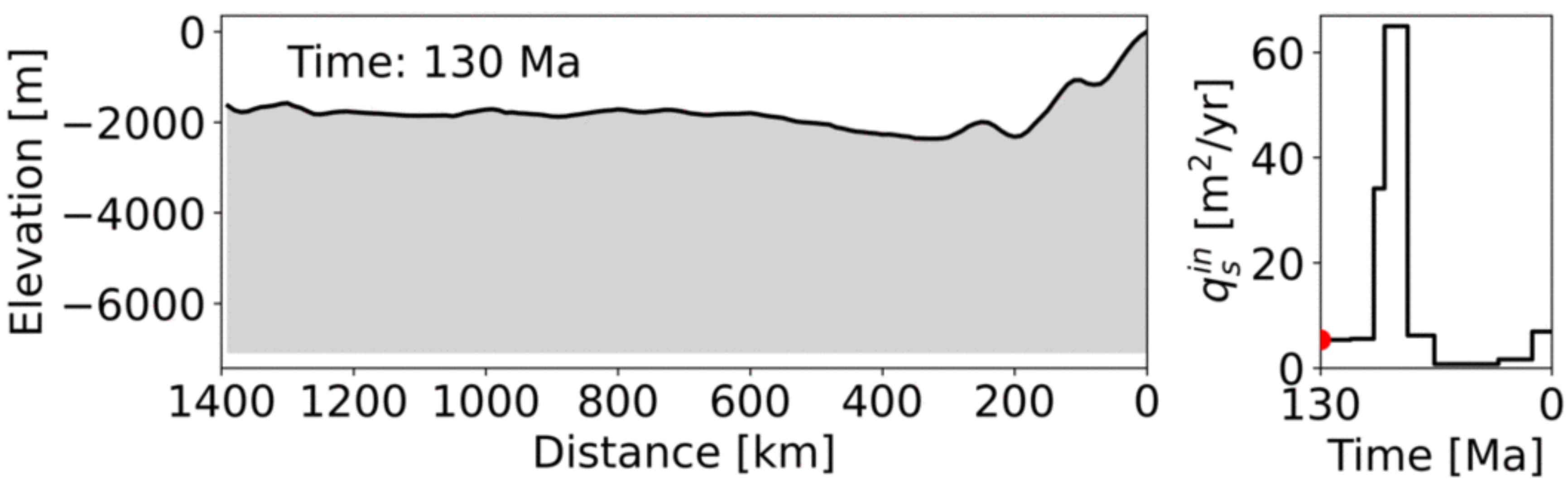
Has a maximum of $D = \frac{q_s}{\lambda}$ when slope is 0

Approaches zero as slope approaches a critical value

Sediment entrainment rate: Linear function of local slope, declines exponentially with water depth

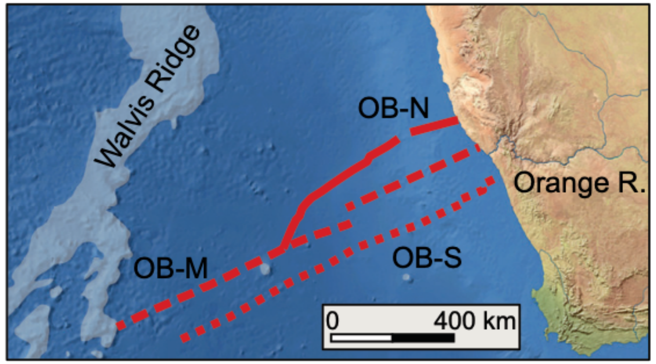
Sediment deposition rate

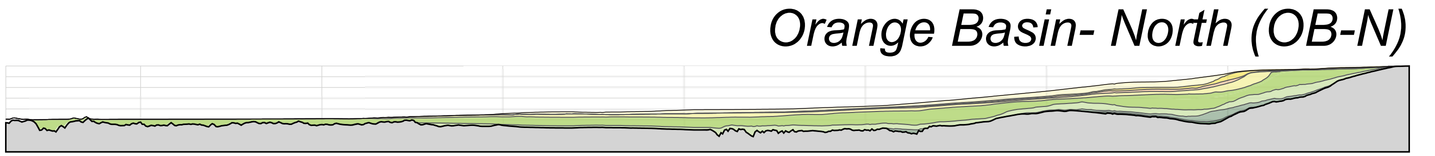
Steckler et al., 1993
Paola, 2000
Carretier et al., 2016
Ding et al., 2019

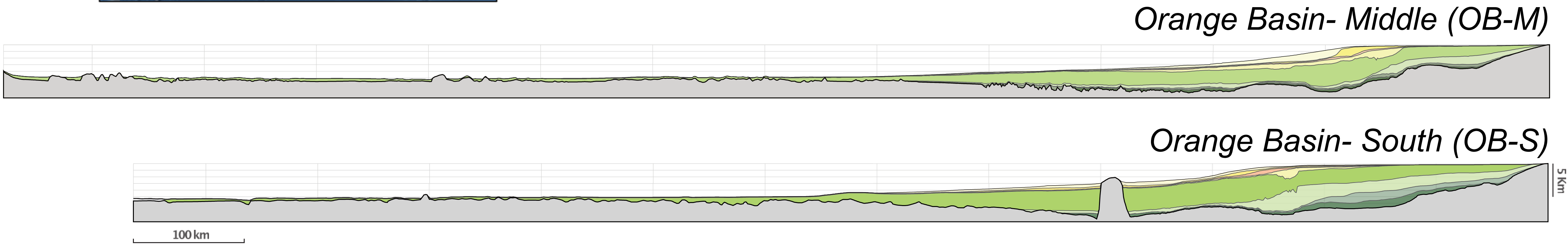


Time: 130 Ma
Elevation [m]
0
−2000
−4000
−6000
1400
1200
1000
800
600
400
200
0
Distance [km]
q_s^{in} [m²/yr]
60
40
20
0
130
0
Time [Ma]

Test case: **Orange Basin**, southern Africa

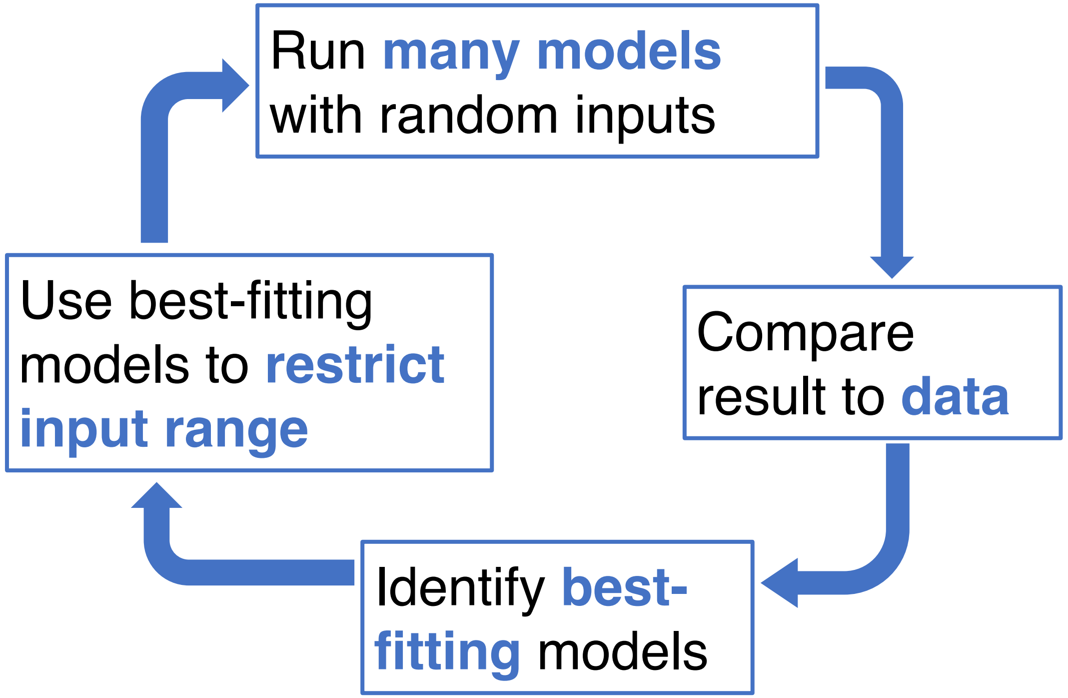




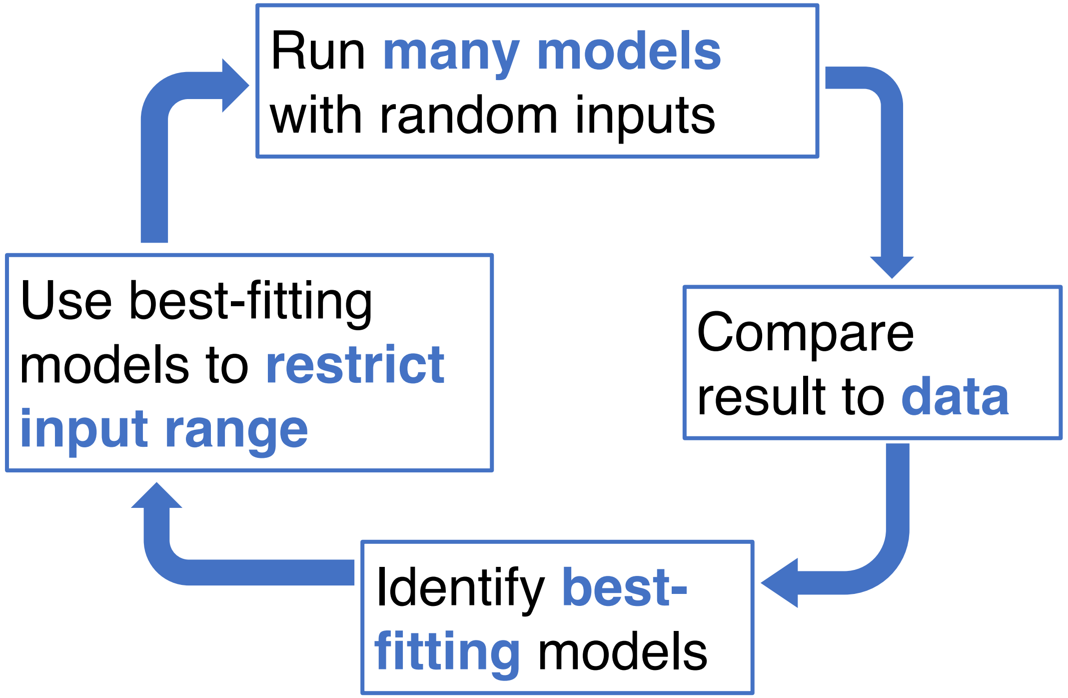


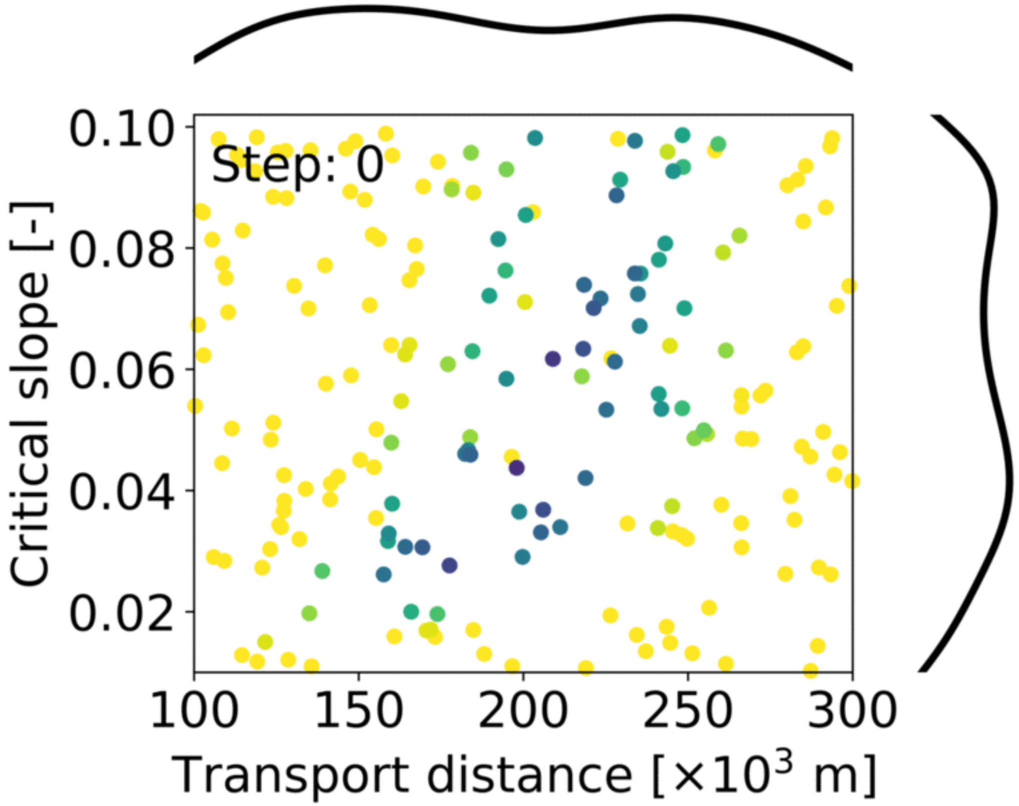
Baby et al., 2018; 2019

What can 10,000 simulations tell us?

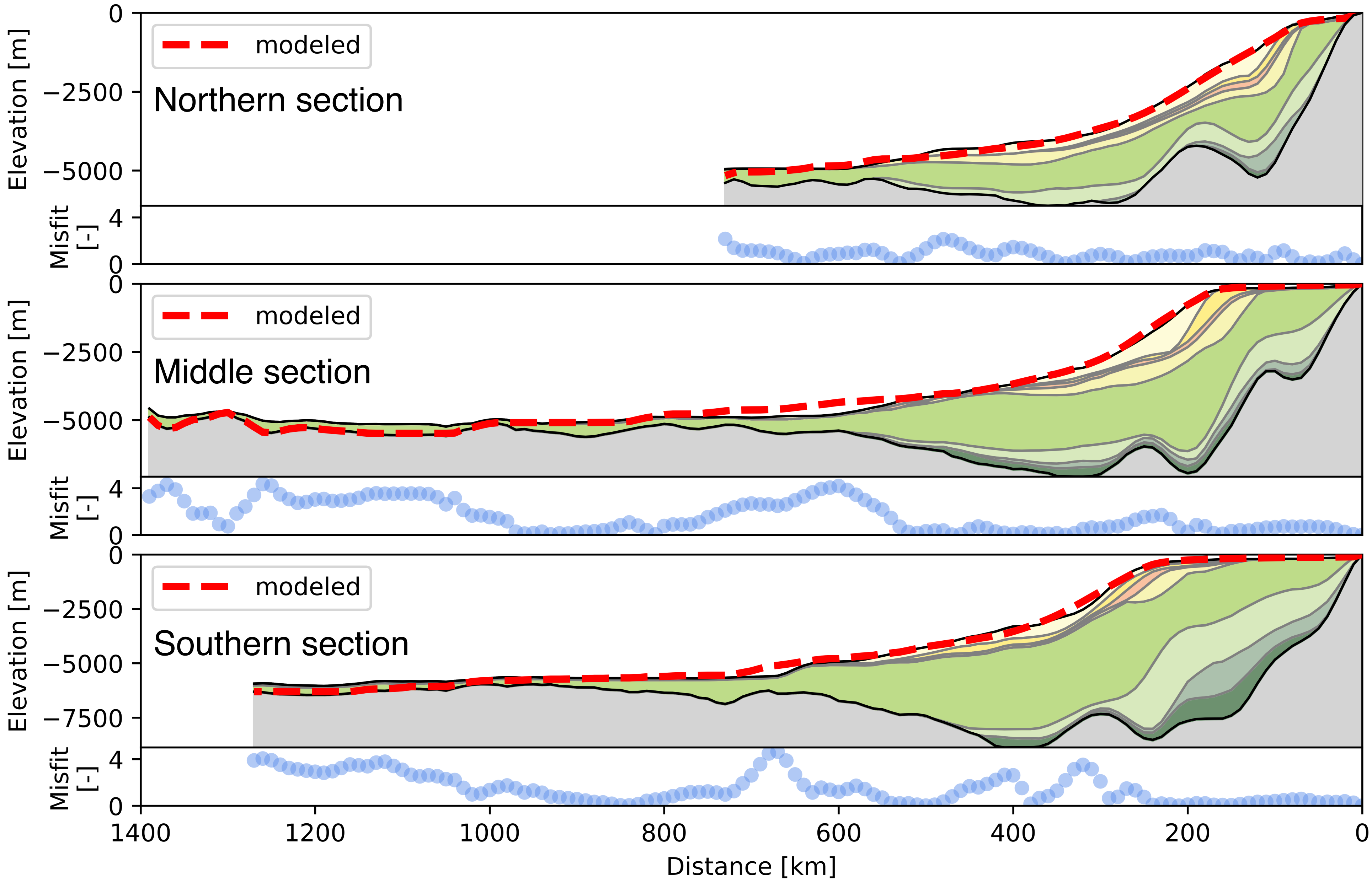


What can 10,000 simulations tell us?



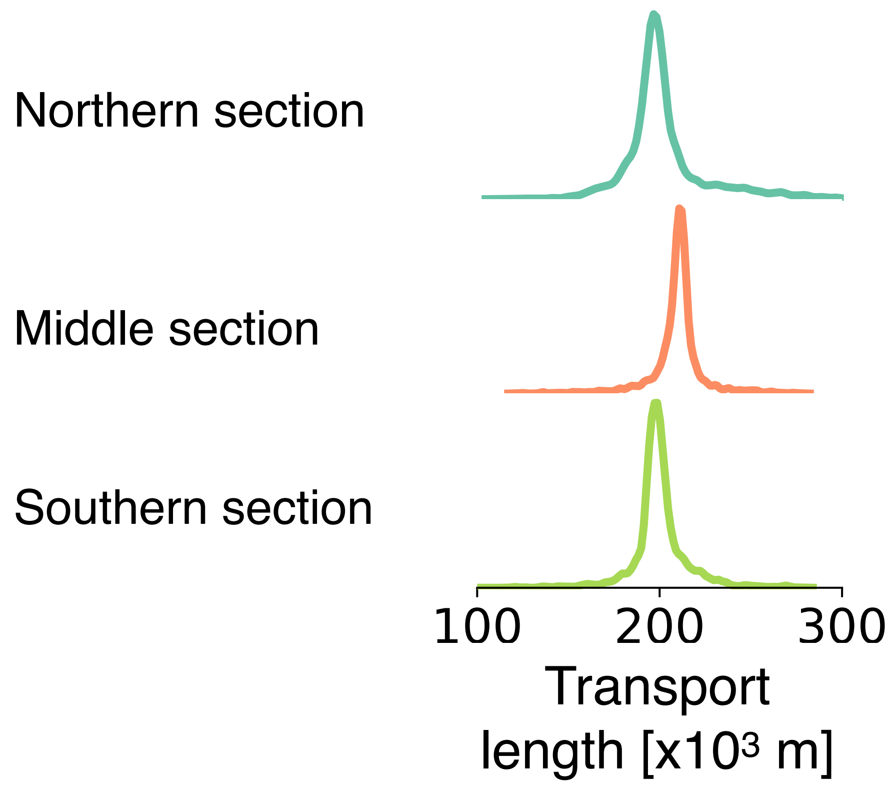


Klinger et al., 2018

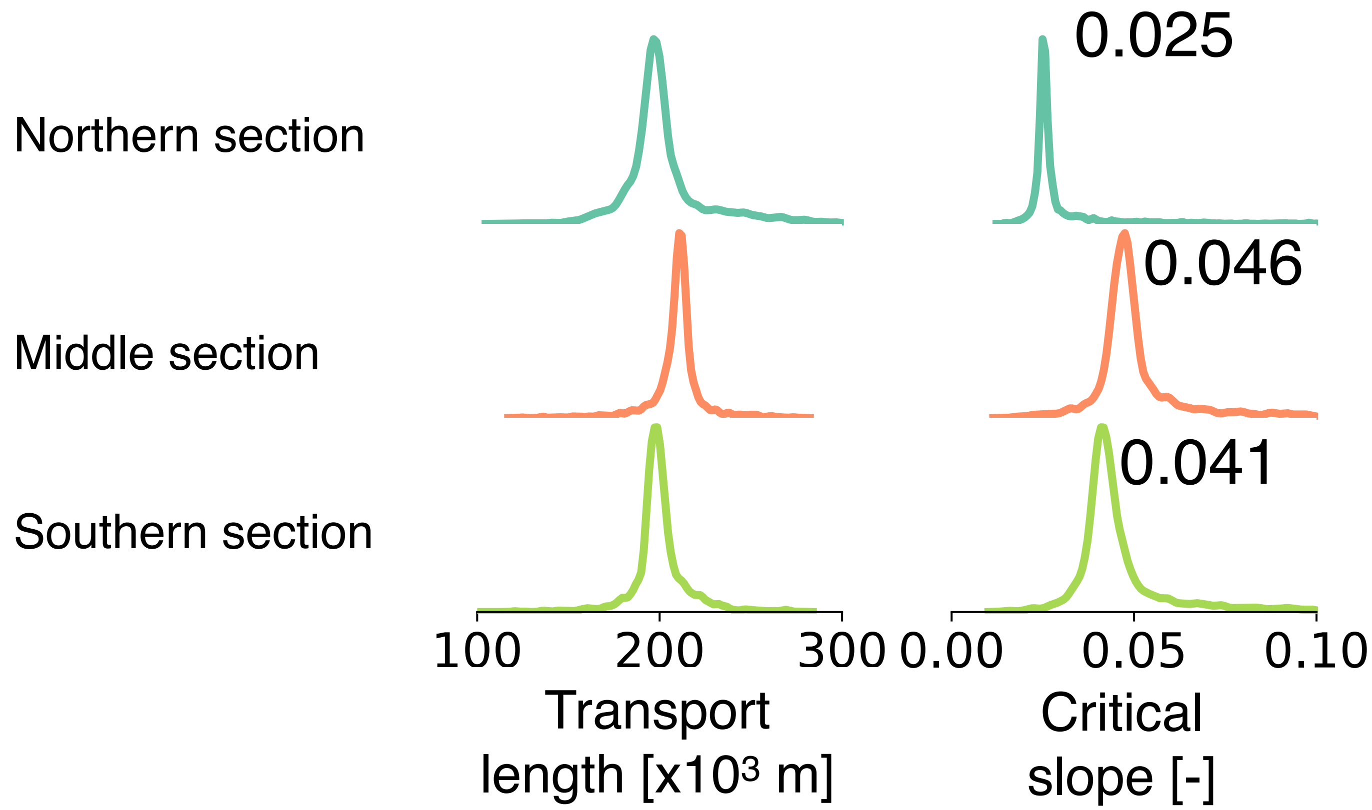


modeled
Northern section
Middle section
Southern section
Elevation [m]
Misfit [-]
0
−2500
−5000
−7500
4
0
1400
1200
1000
800
600
400
200
0
Distance [km]

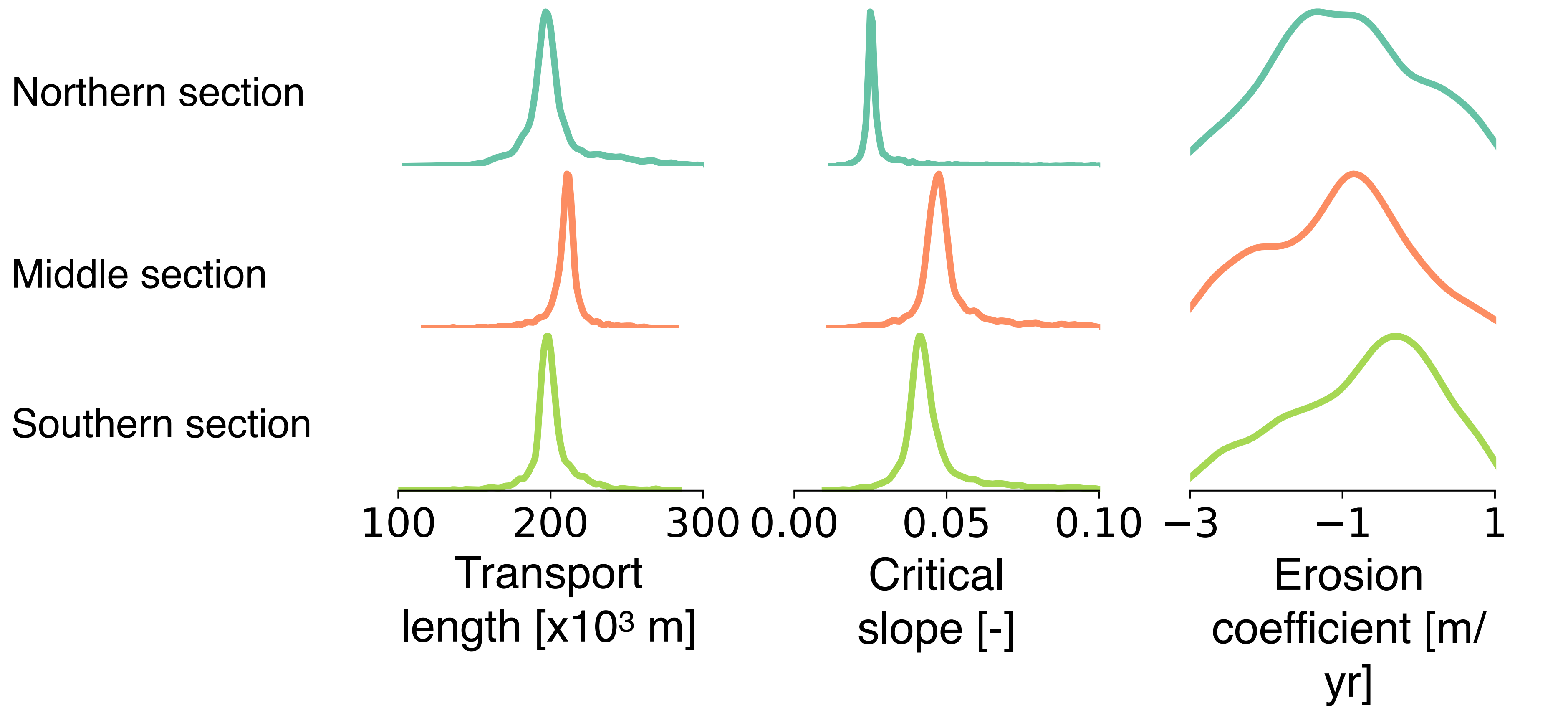
10,000 simulations reveal **constant transport length**

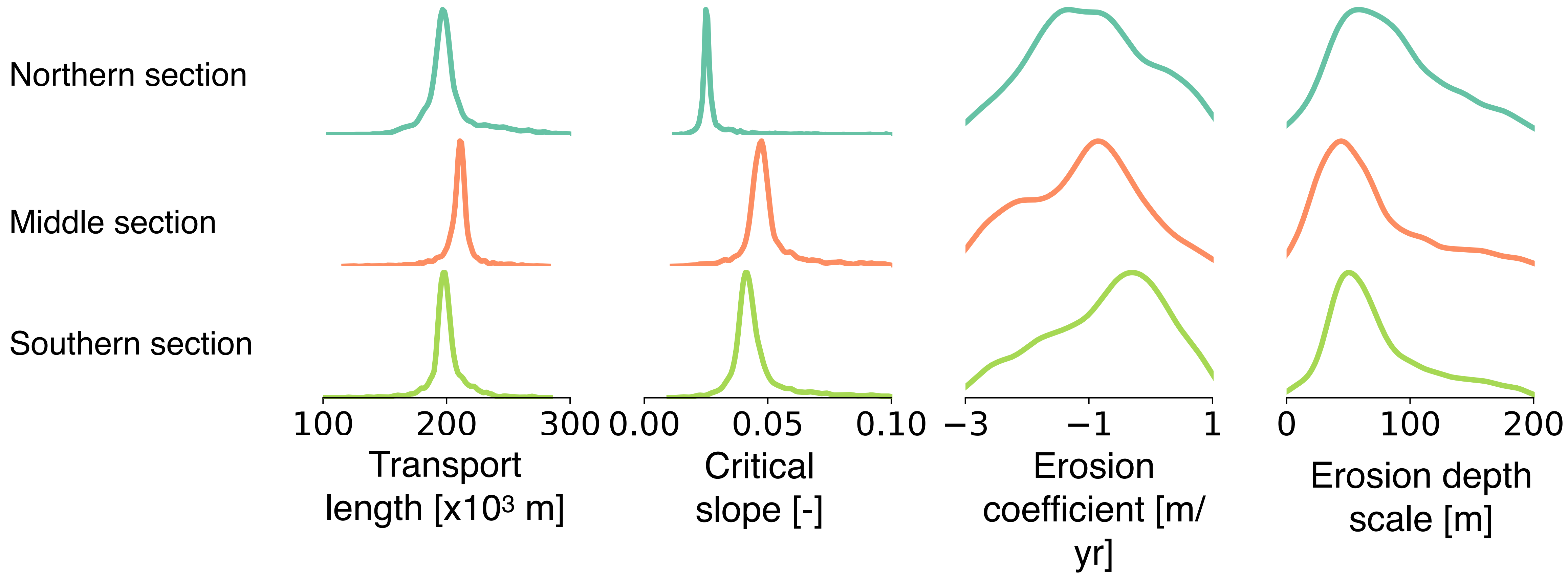


10,000 simulations reveal **consistent critical slope**

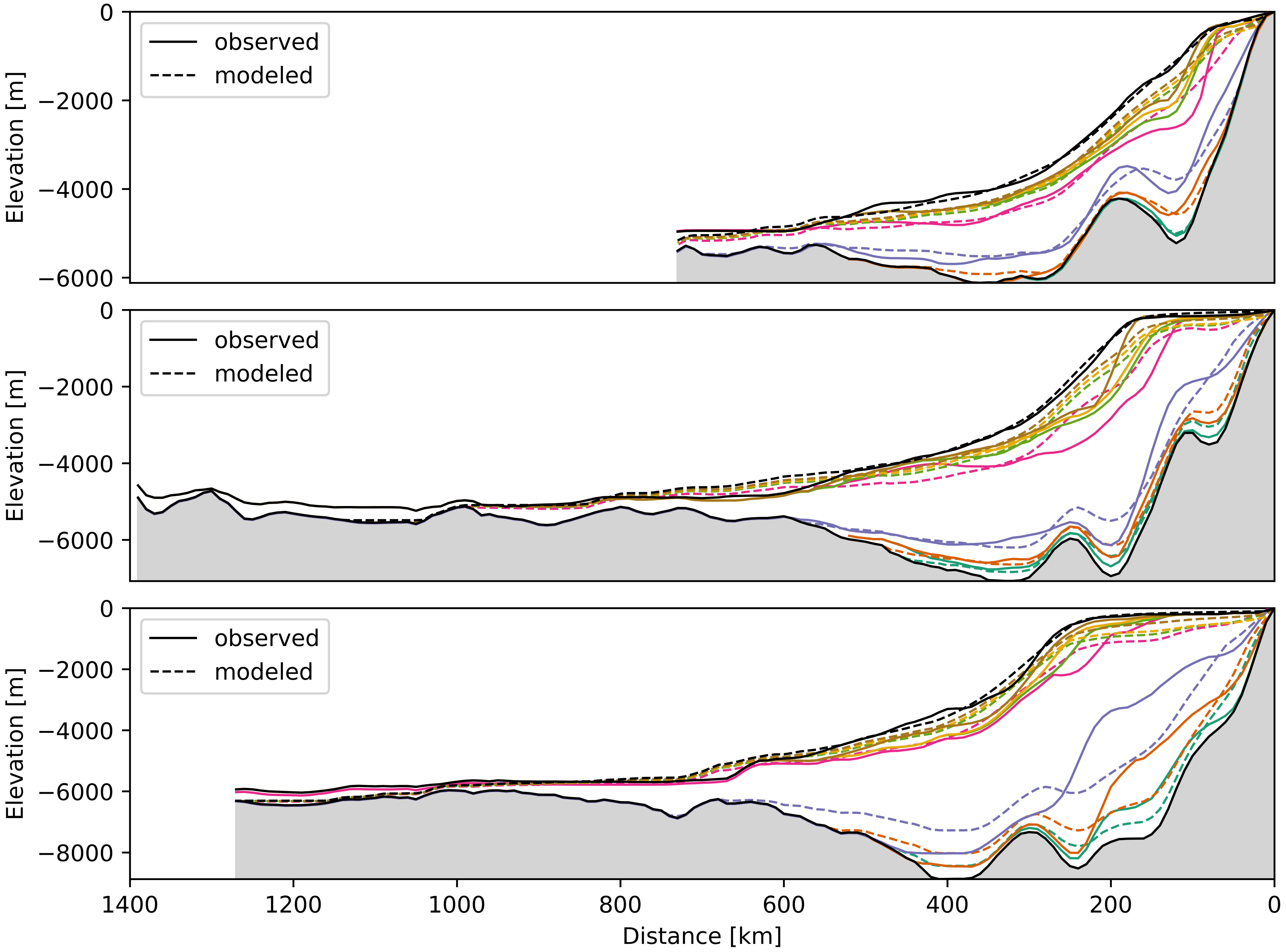


10,000 simulations reveal **little erosion influence**



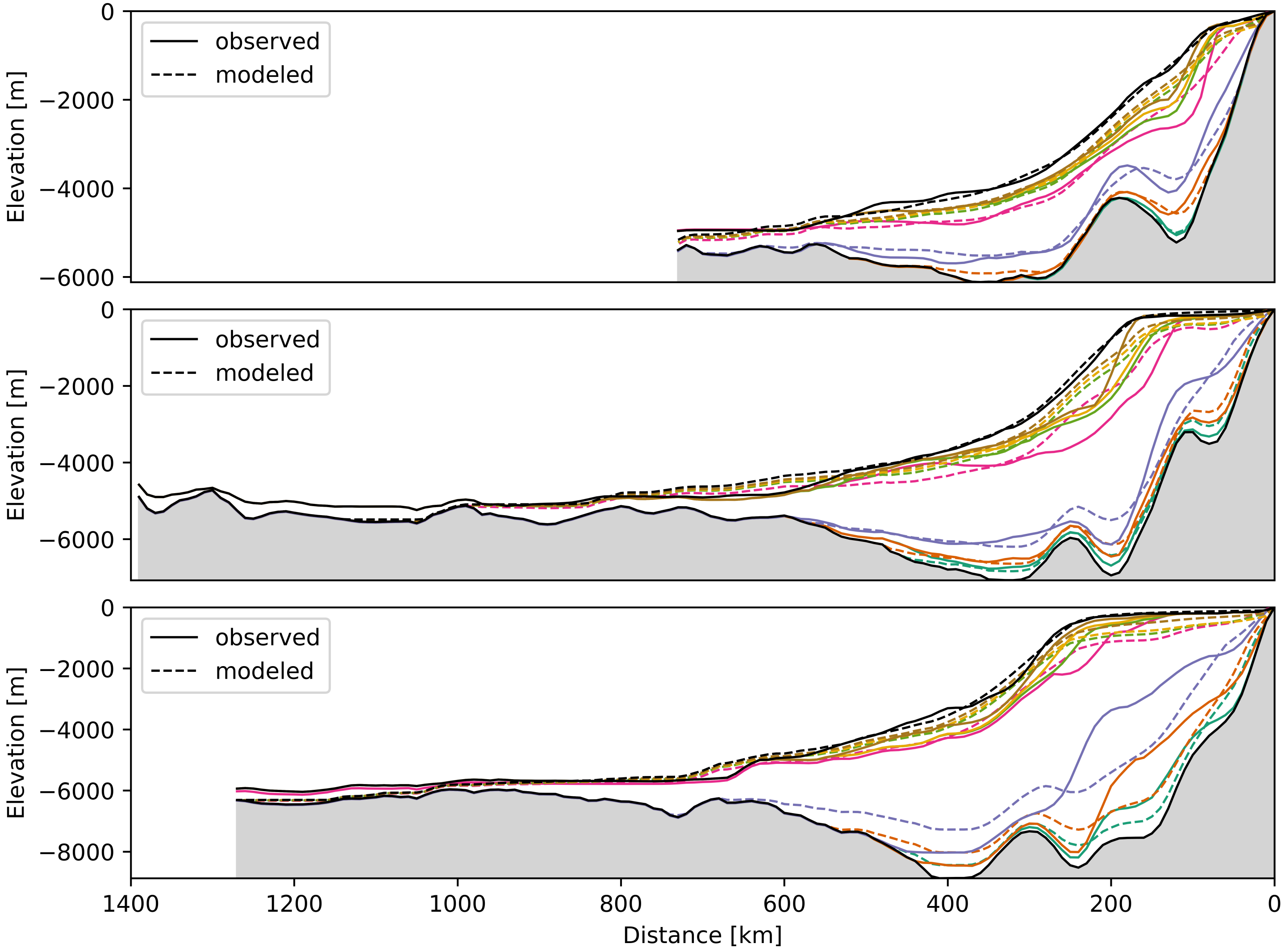


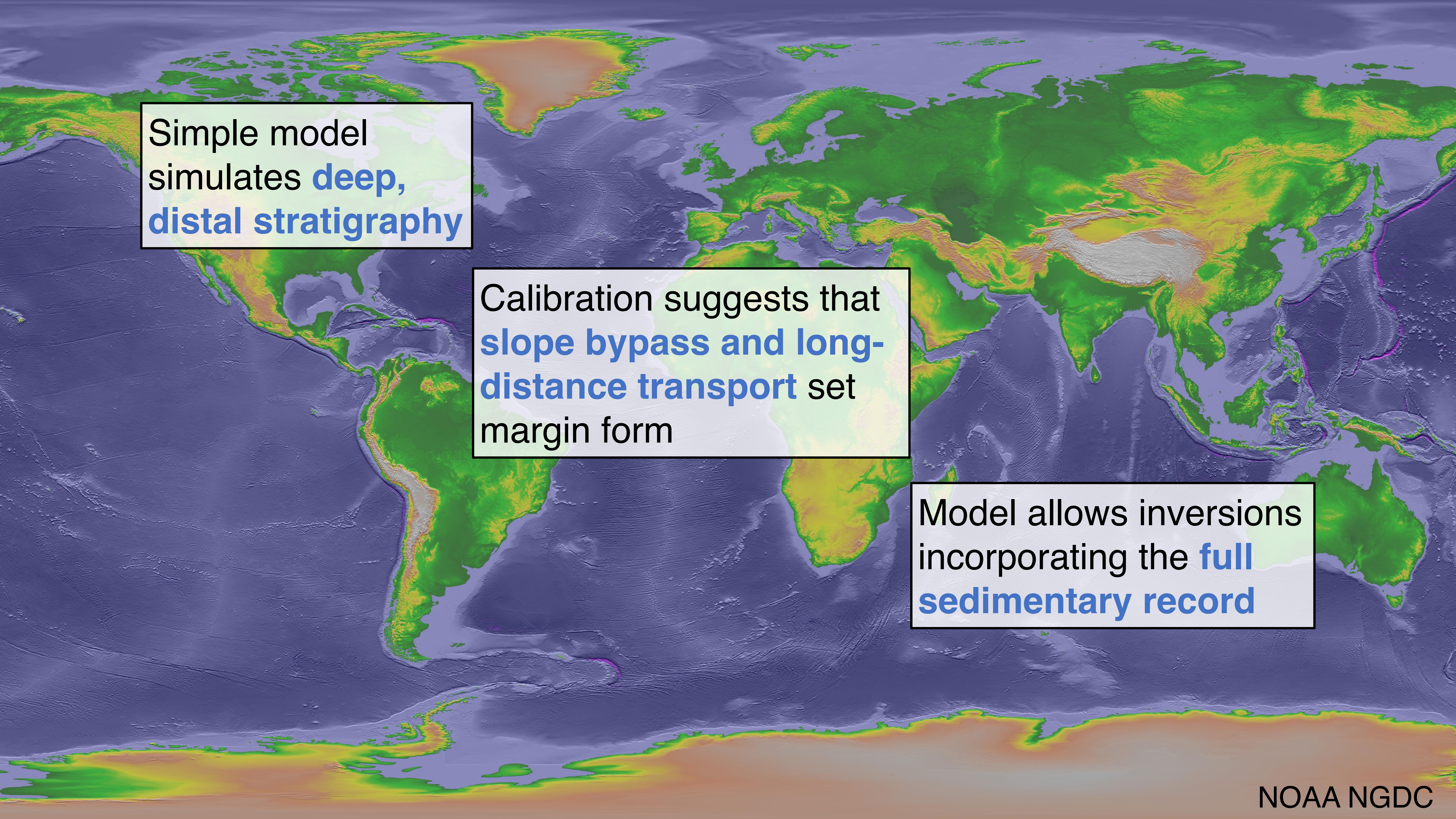
Northern section
Middle section
Southern section
100
200
300
0.00
0.05
0.10
−3
−1
1
0
100
200
Transport length [x10³ m]
Critical slope [-]
Erosion coefficient [m/yr]
Erosion depth scale [m]



observed
modeled
Elevation [m]
0
−2000
−4000
−6000
−8000
Distance [km]
1400
1200
1000
800
600
400
200
0

Middle section




Simple model simulates **deep, distal stratigraphy**
Calibration suggests that **slope bypass and long-distance transport** set margin form
Model allows inversions incorporating the **full sedimentary record**
NOAA NGDC