Inverting passive margin stratigraphy for marine sediment transport dynamics over geologic time

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

- Forward stratigraphic models typically assume that marine sediment transport is proportional to local slope.
- This approach gives reasonable stratigraphy in shallow/nearshore environments, but likely underpredicts deep marine deposit thickness.
- We propose a simple modification that allows 1) sediment bypass on steep slopes and 2) transport over negligible slopes.
- Here we test the two models against stratigraphic data.

Model in 1-D; deposition term changes with local slope

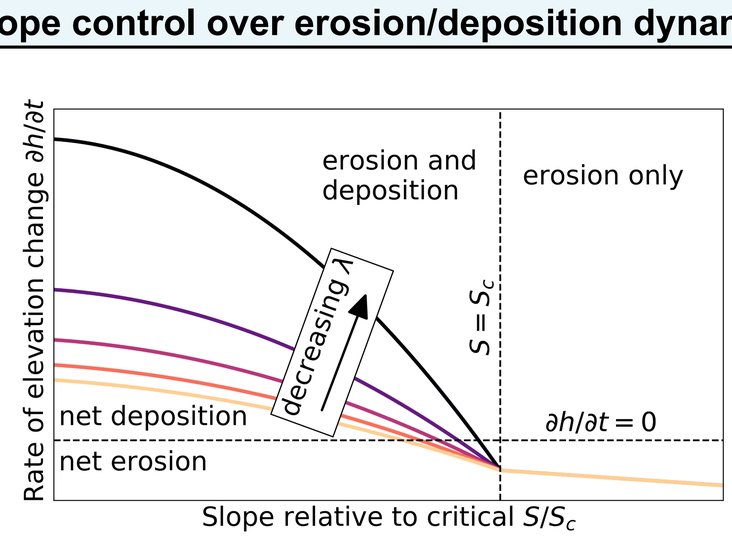
Topographic change = Flux imbalance

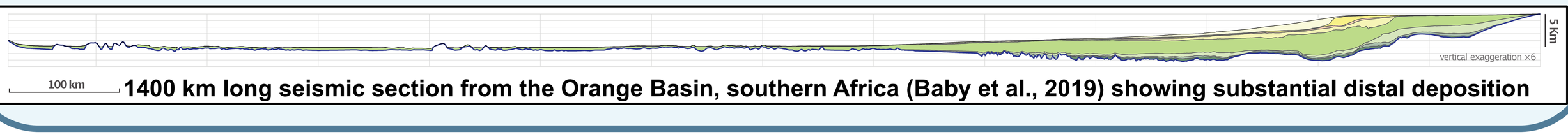
$$\frac{\partial \eta}{\partial t} = -\frac{\partial q_s}{\partial x} = -E + D$$

- E: Sediment entrainment rate: Linear function of local slope, declines exponentially with water depth
- D: Sediment deposition rate. Has a maximum of $D = \frac{q_s}{\lambda}$ when slope is 0. Approaches zero as slope approaches a critical value

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

Slope control over erosion/deposition dynamics





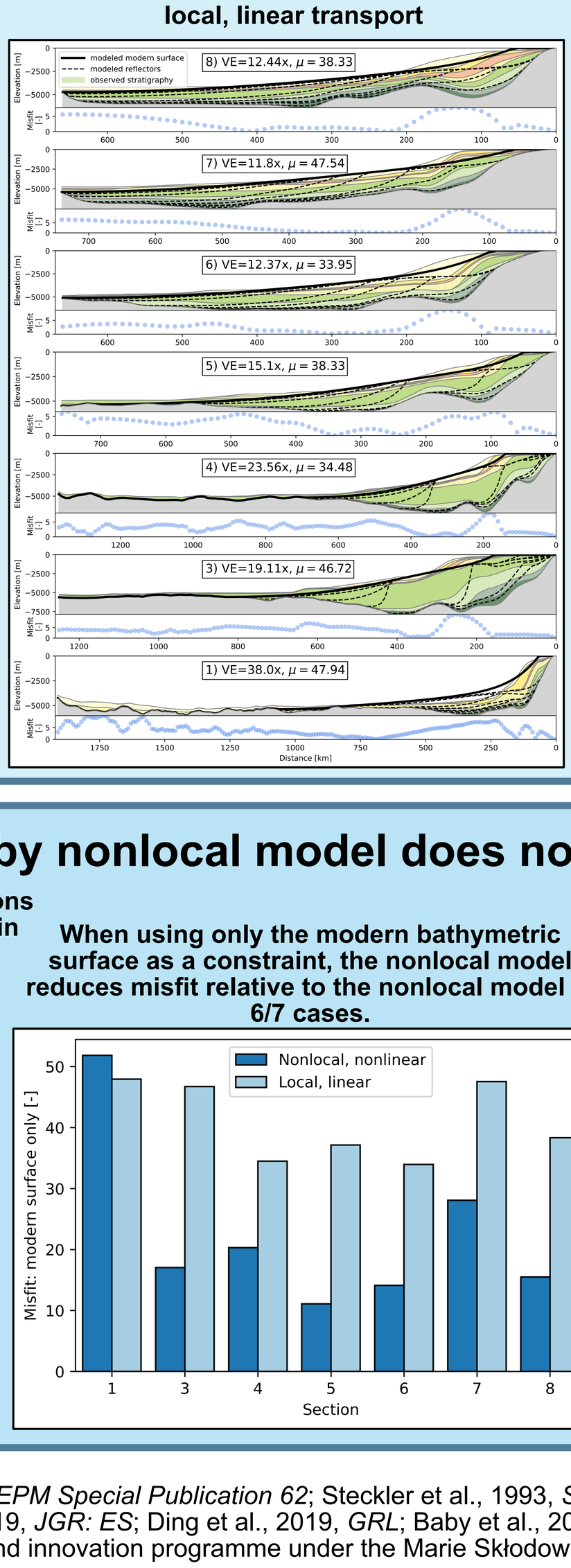
1400 km long seismic section from the Orange Basin, southern Africa (Baby et al., 2019) showing substantial distal deposition

Testing local versus nonlocal models using stratigraphy from the Orange Basin, southern Africa

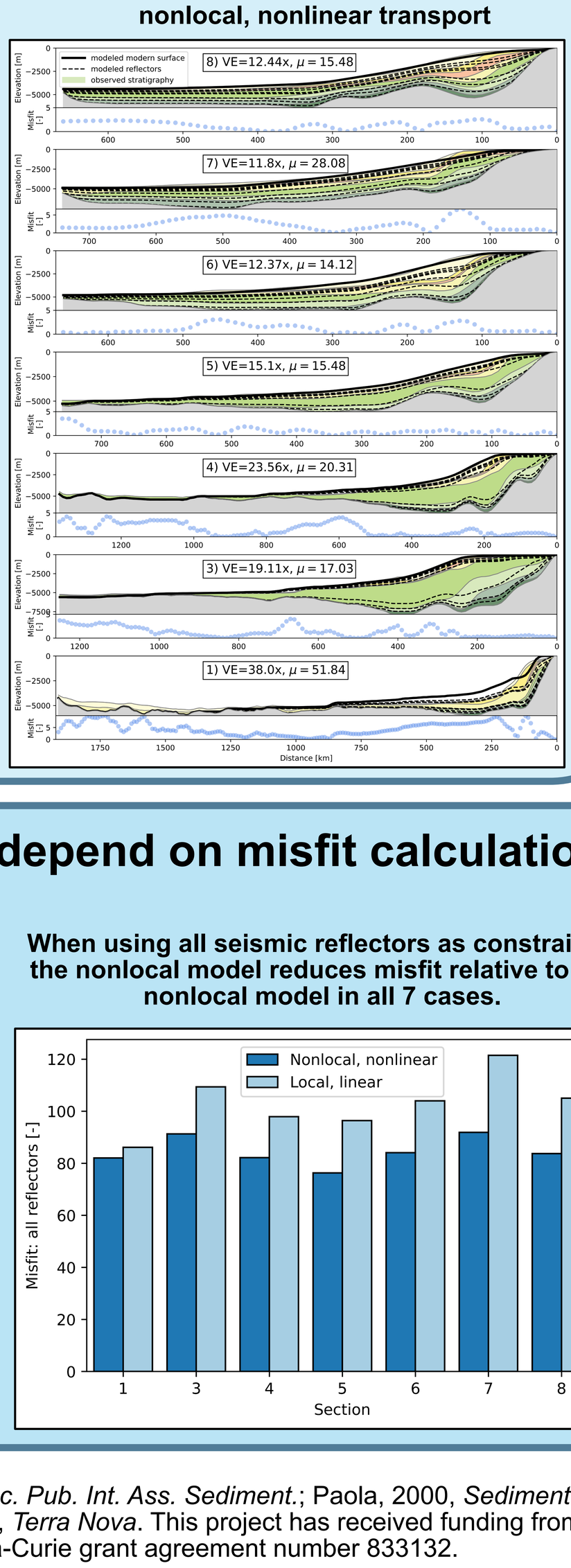
- We compare modeled 1-D stratigraphic profiles evolved over 130 Ma to seven interpreted seismic sections from the Orange Basin.
- Likelihood-free approximate Bayesian computation finds the model parameters that produce the best model-data match. Best-fit simulations for the local and nonlocal models are then compared against the stratigraphic data to assess misfit.
- Best-fit results for 6/7 or 7/7 (depending on the misfit calculation) sections suggest that **long-distance, nonlocal transport is required** to match observed stratigraphy.

Scan to read the preprint on EarthArxiv!

Model-data comparison: local, linear transport

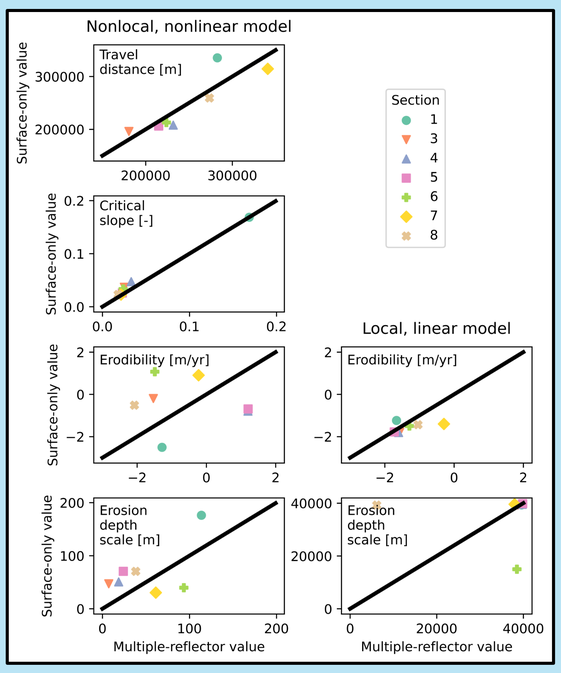


Model-data comparison: nonlocal, nonlinear transport



Improvement given by nonlocal model does not depend on misfit calculation

Comparing two different misfit calculations does not reveal consistent differences in best-fit parameter values.



When using only the modern bathymetric surface as a constraint, the nonlocal model reduces misfit relative to the nonlocal model in 6/7 cases.

When using all seismic reflectors as constraints, the nonlocal model reduces misfit relative to the nonlocal model in all 7 cases.

References: Granjeon and Joseph, 1999, *SEPM Special Publication 62*; Steckler et al., 1993, *Spec. Pub. Int. Ass. Sediment.*; Paola, 2000, *Sedimentology*; Carretier et al., 2016, *ESurf*; Yuan et al., 2019, *JGR: ES*; Ding et al., 2019, *GRL*; Baby et al., 2019, *Terra Nova*. This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement number 833132.