Inversion of marine stratigraphy for optimal seascape evolution model structure and parameters

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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 (e.g., Yuan et al., 2019).
- This approach gives reasonable stratigraphy in shallow/nearshore environments, but underpredicts deep marine deposit thickness.
- We propose a simple modification that allows 1) sediment bypass on steep slopes and 2) transport over negligible slopes.

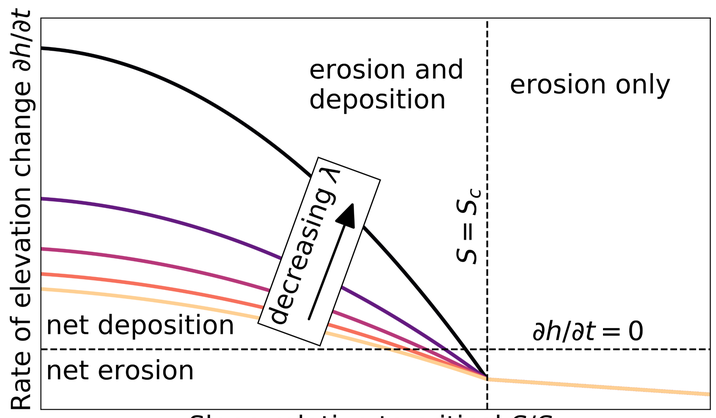
Model in 1-D; deposition term changes with local slope

Topographic change: $\frac{\partial \eta}{\partial t}$ = Flux imbalance: $-\frac{\partial q_s}{\partial x}$ = $-E + D$

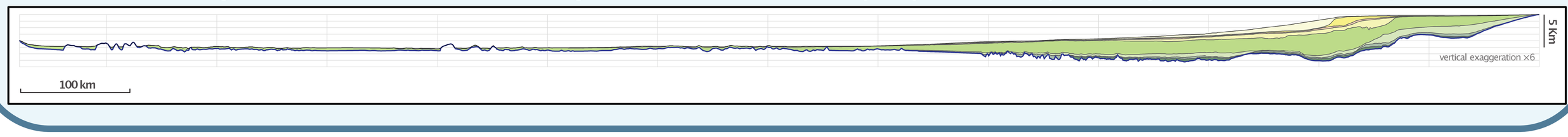
- E: Sediment entrainment rate: Linear function of local slope, declines exponentially with water depth
- D: Sediment deposition rate; Has a maximum of $D = \frac{q_s}{\lambda}$ when slope is 0; Approaches zero as slope approaches a critical value

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

Slope control over erosion/deposition dynamics



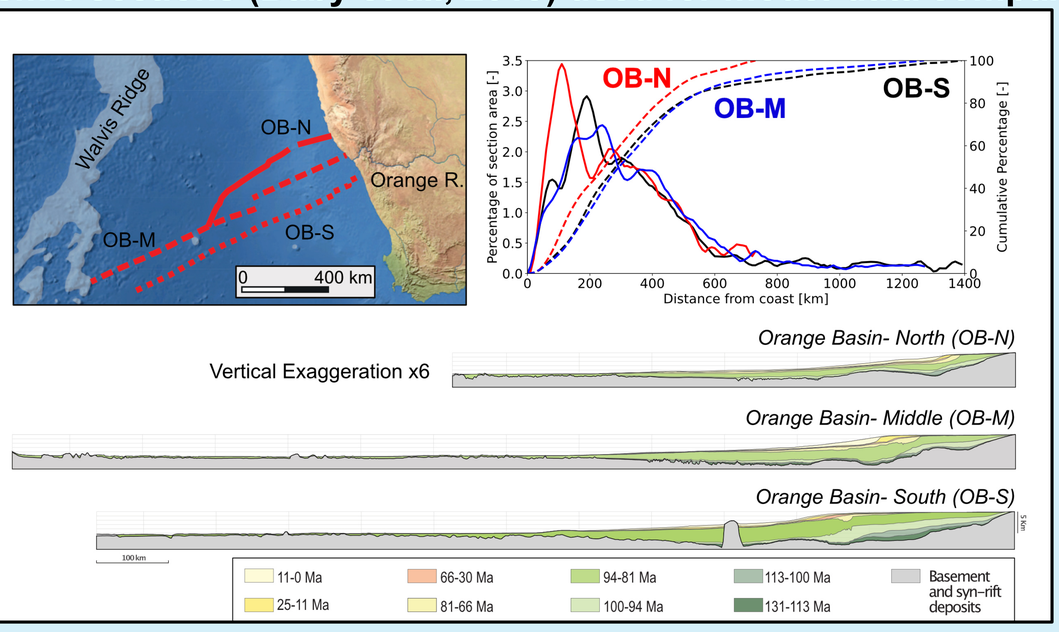
1400 km long seismic section from the Orange Basin, southern Africa (Baby et al., 2019) showing substantial distal deposition



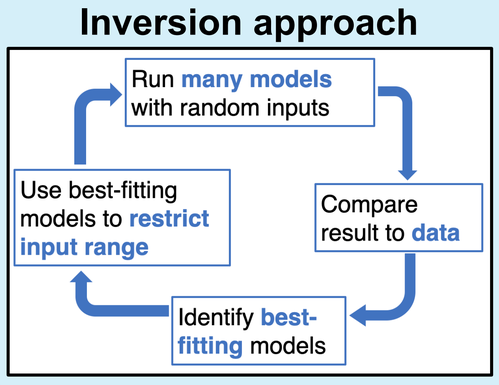
Inversion using stratigraphy from the Orange Basin, southern Africa

- We compare modeled 1-D stratigraphic profiles evolved over 130 Ma to three interpreted seismic sections from the Orange Basin.
- Likelihood-free approximate Bayesian computation finds the model parameters that produce the best model-data match.
- Parameter values reveal the relative importance of local versus nonlocal sediment transport, and the slope at which bypass occurs.
- Best-fit results for all three sections suggest that **long-distance, nonlocal transport is required** to match modeled and observed stratigraphy.
- While the best-fit transport distance parameter is consistent among the three seismic sections, the best-fit critical slope varies substantially.

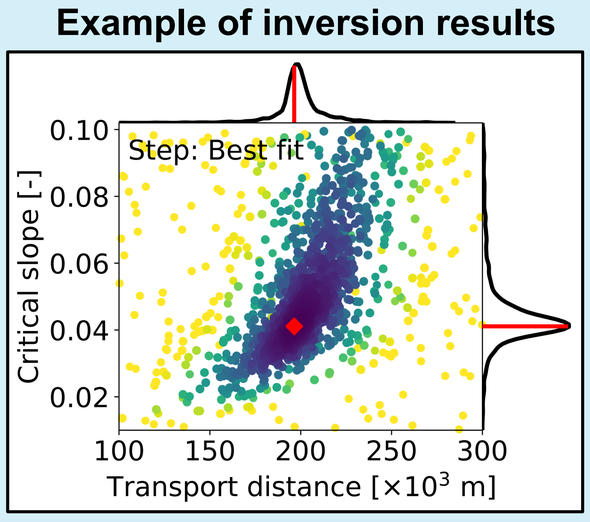
Seismic sections (Baby et al., 2019) used for model-data comparison



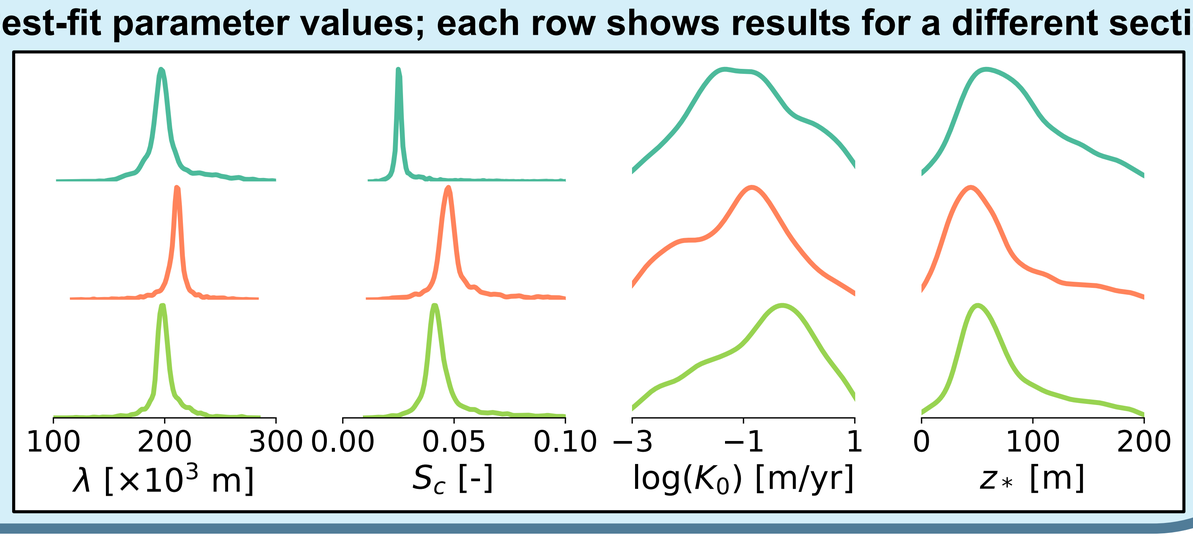
Inversion approach



Example of inversion results

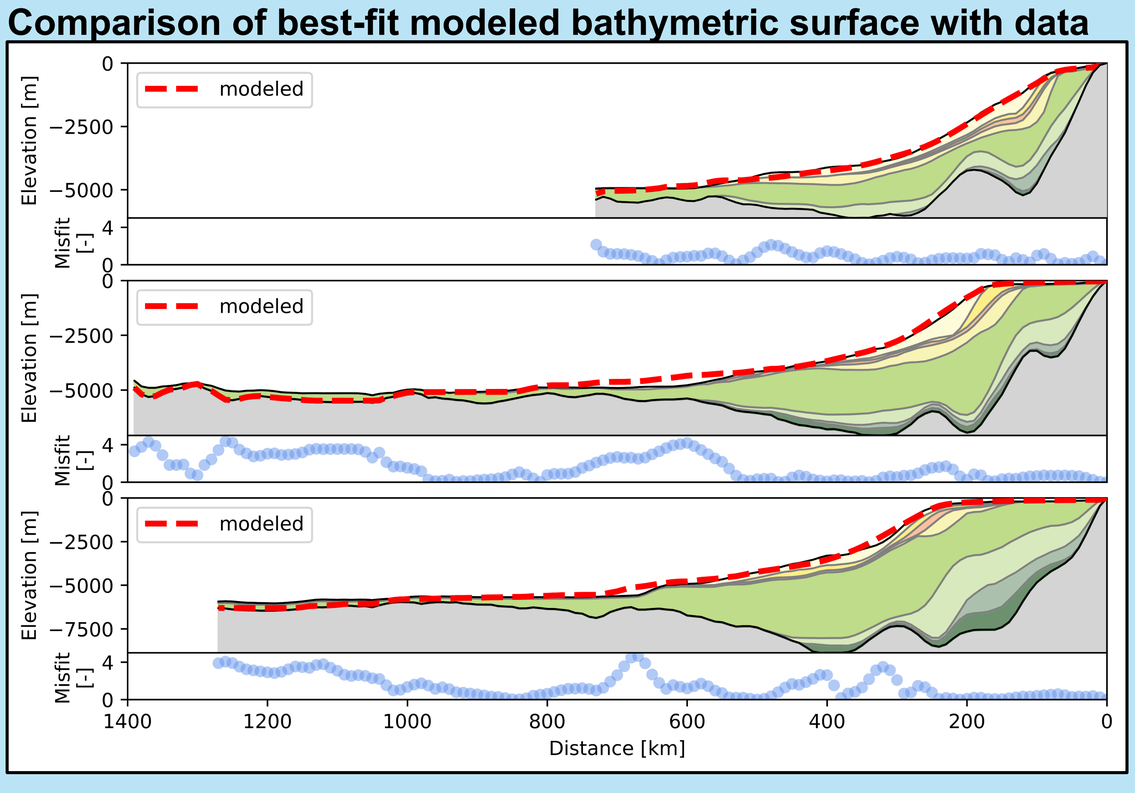


Best-fit parameter values; each row shows results for a different section

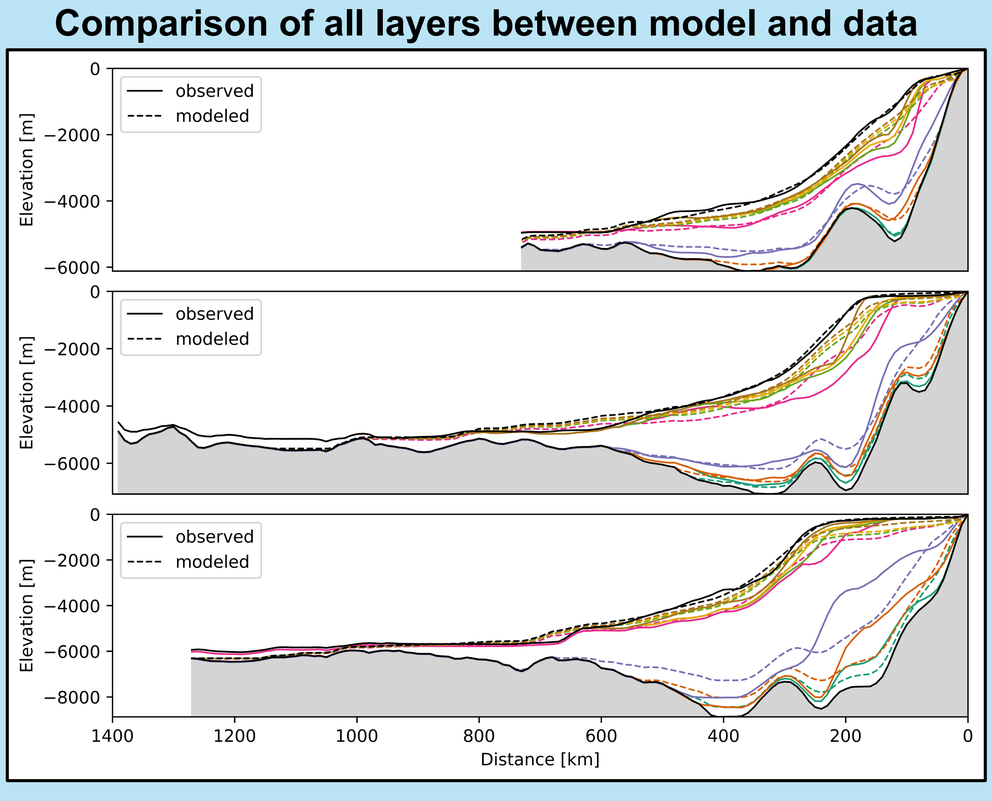


Model-data (mis)fit: some success and some room for improvement

Comparison of best-fit modeled bathymetric surface with data



Comparison of all layers between model and data



References: 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.