The Effect of Grain-Size Distribution on Fluid-Sediment Feedback

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TSSAR-Waves

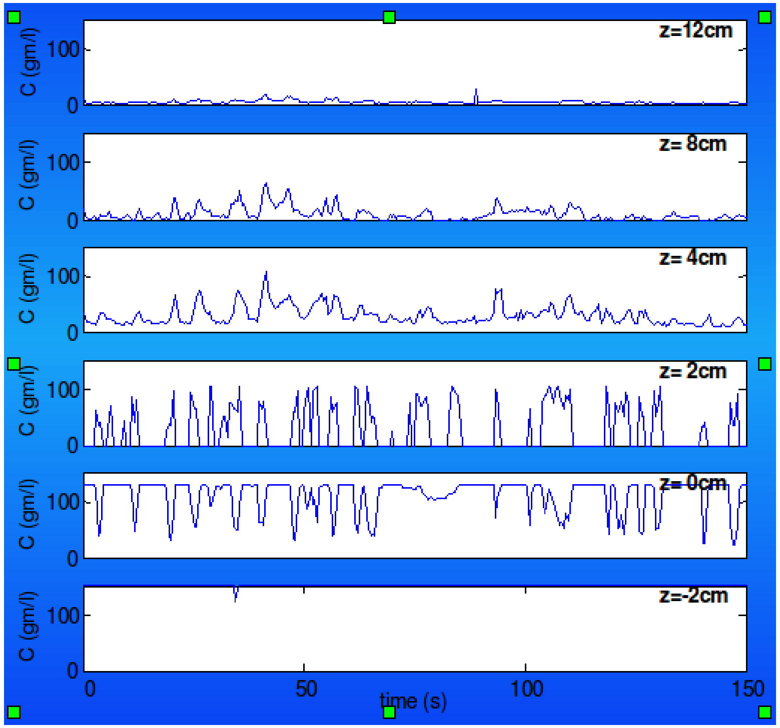
(Turbulence, Sediment Stratification and Altered Resuspension under Waves)

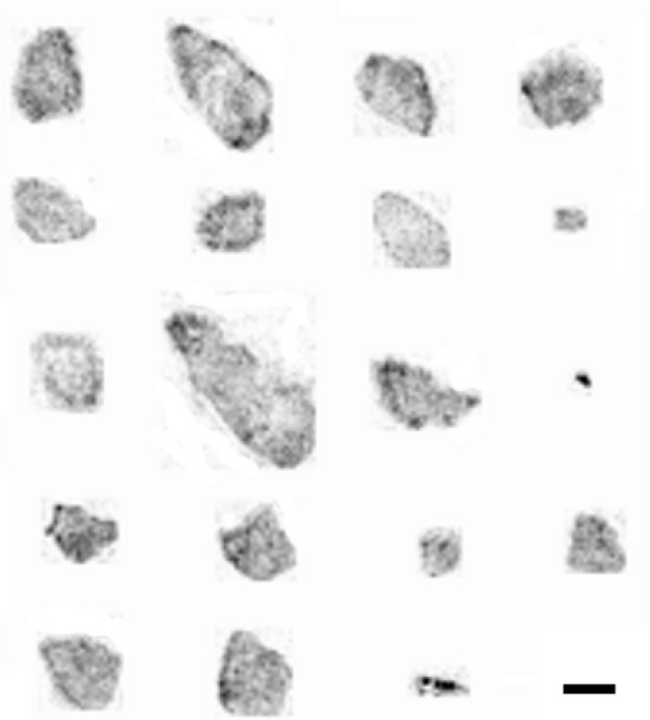
Hypotheses

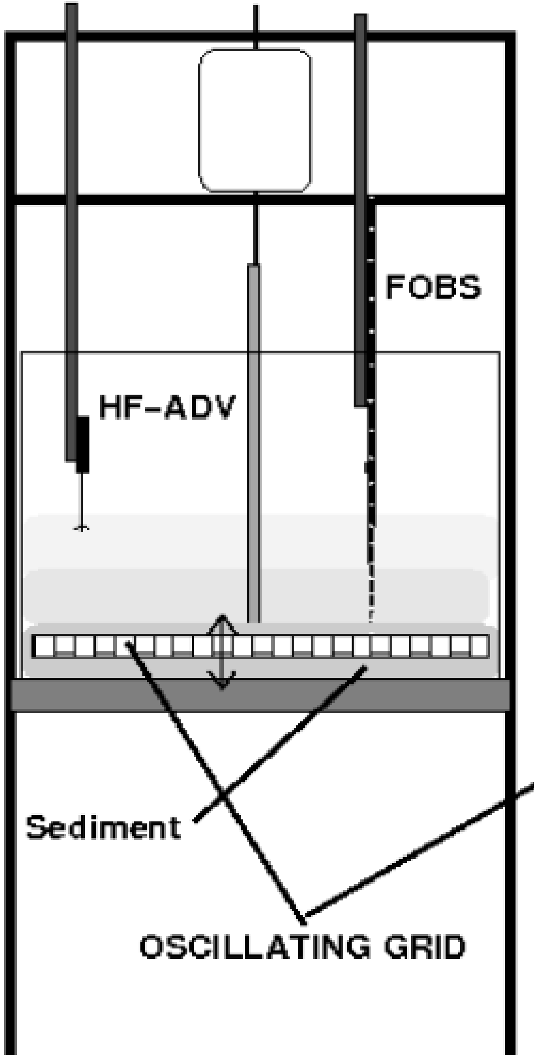
http://www.research.plymouth.ac.uk/tssar_waves/

→two-way feedback between instantaneous flow stratification by suspended sediment and the turbulence is a key factor in the generation of nearshore morphology.

→the nature of this feedback is fundamentally dependant on the distribution of grain sizes.







Outline

Sediment boundary condition is perhaps the least well constrained aspect of phase-resolving sediment transport models

We've examined how individual size classes are entrained when the bed sediment contains a mixture of sediment sizes

We've identified 3 fundamentally different approaches to the problem, and for each compared modelled grain-size distributions of mobilized sediment to observations

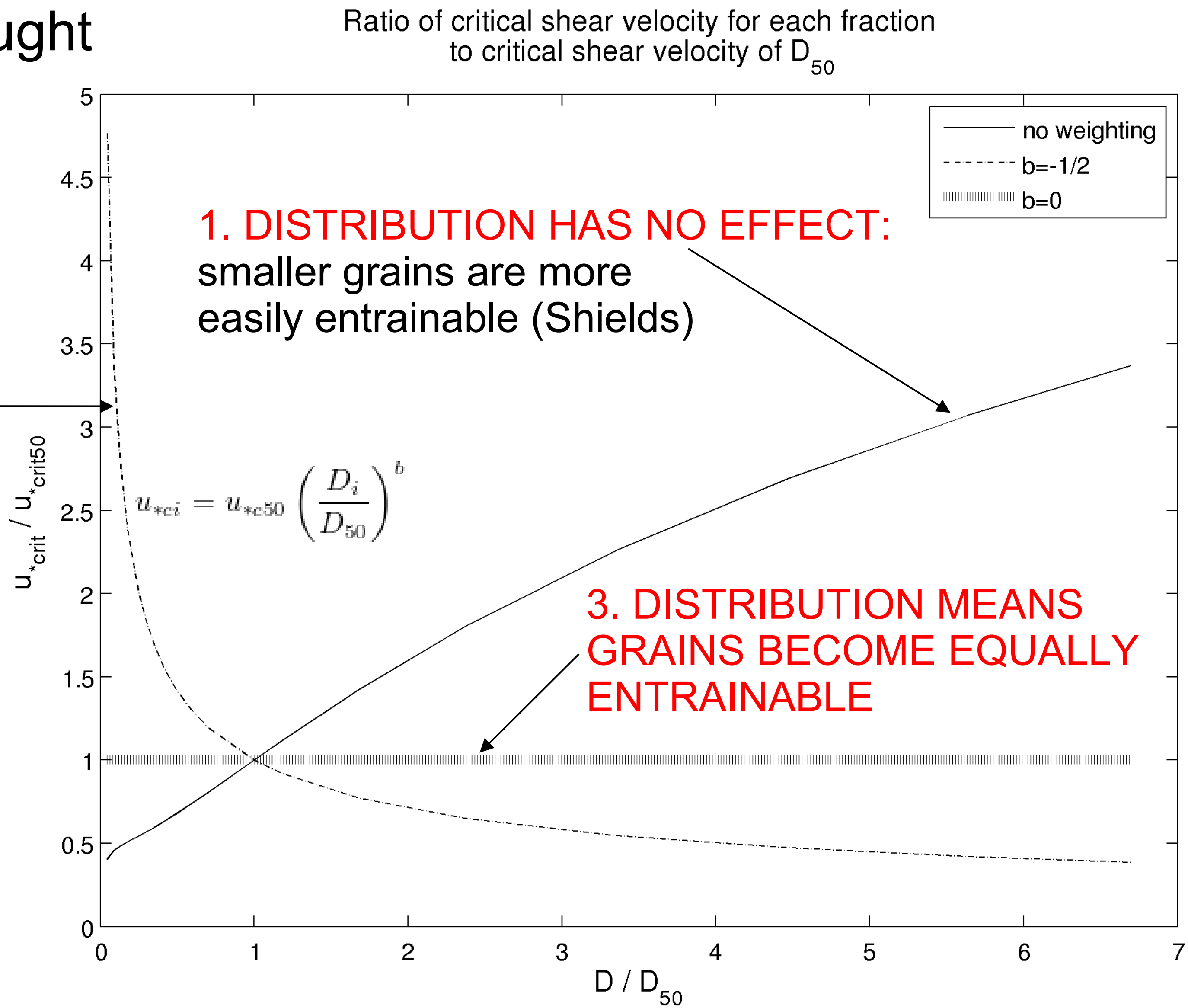
For now, we've limited this analysis to steady flows

Entrainment in a Mixed Bed

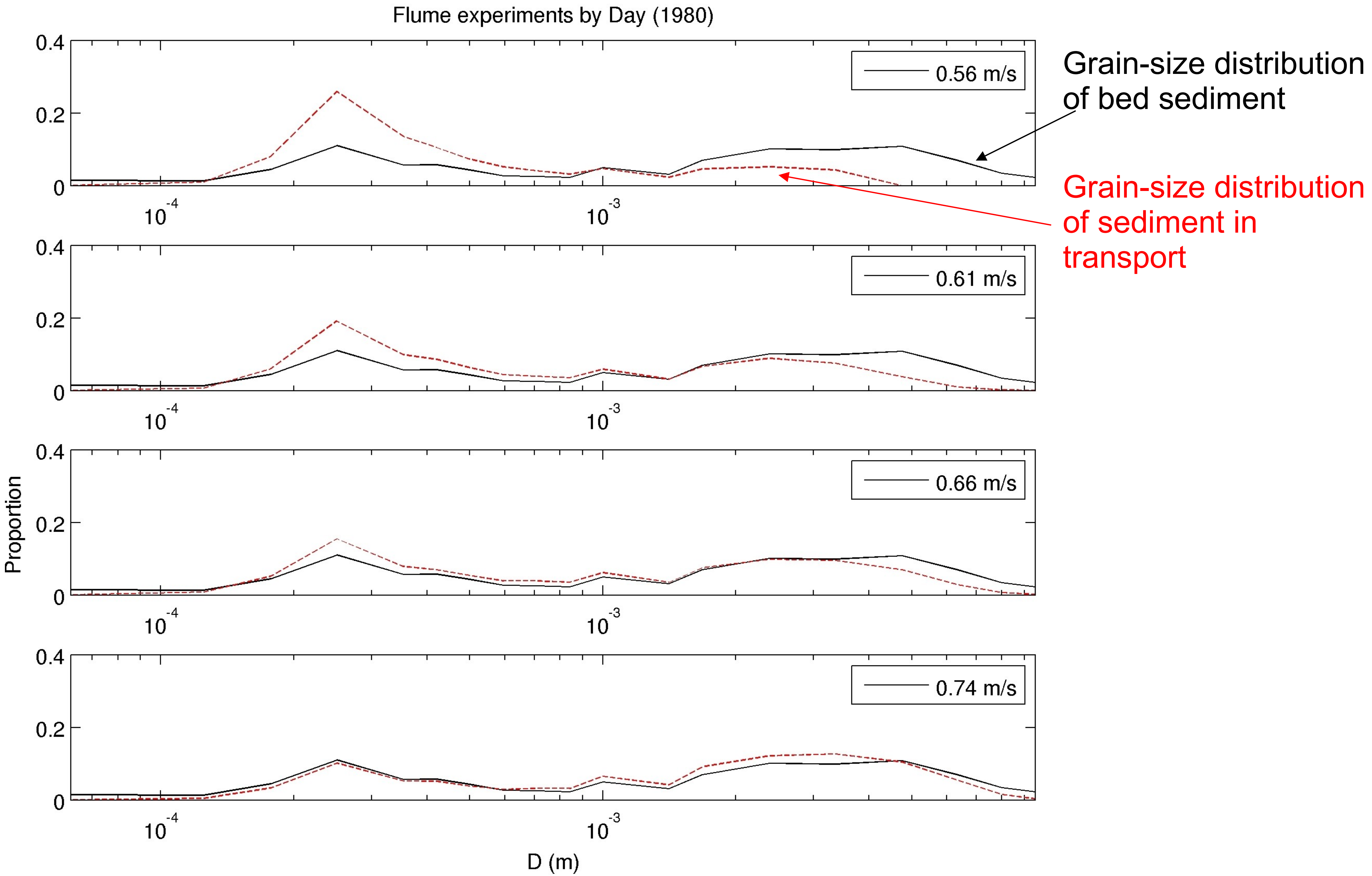
At least 3 schools of thought in the literature:

2. DISTRIBUTION 'REVERSES ENTRAINABILITY':
smaller grains in a mixture show greater resistance to movement than in a mono-size bed

Larger grains show less resistance to movement in a mixture



Poorly-Sorted Mixed Bed Data



Model

Modified version of GOTM (General Ocean Turbulence Model) used to recreate flume Hydraulics.

$$u_* = \frac{\kappa\sqrt{u^2+v^2}}{\ln((z+z_0)/z_0)}$$

Shear velocity calculated using a log-layer approximation

$$C_{0i} = \gamma V_i \left[\left(\frac{u_*}{u_{*ci}} \right)^2 - 1 \right] \qquad z_0 = 0.03 h_0$$

Smith & McLean (1977) reference concentration.

Proportion of excess stress used to mobilise a sediment size class equal to proportion of bottom sediment it represents. Presence of distribution has no effect

$$u_{*ci} = \sqrt{\theta_c (s-1) g D_i} \qquad \theta_c = \frac{0.24}{D_*} + 0.055[1 - \exp(-0.02 D_*)]$$

Soulsby & Whitehouse (1997) expression for critical shear velocity

$$C_{0i} = \gamma V_i \left[\left(\frac{u_*}{u_{*c50} \left(D_i/D_{50}\right)^b} \right)^2 - 1 \right]$$

Modified Smith & McLean (1977) reference concentration for effects of distribution.

Tested conditions:
b = -0.5 (enhanced coarse grain mobility)
b = 0 (equal mobility)

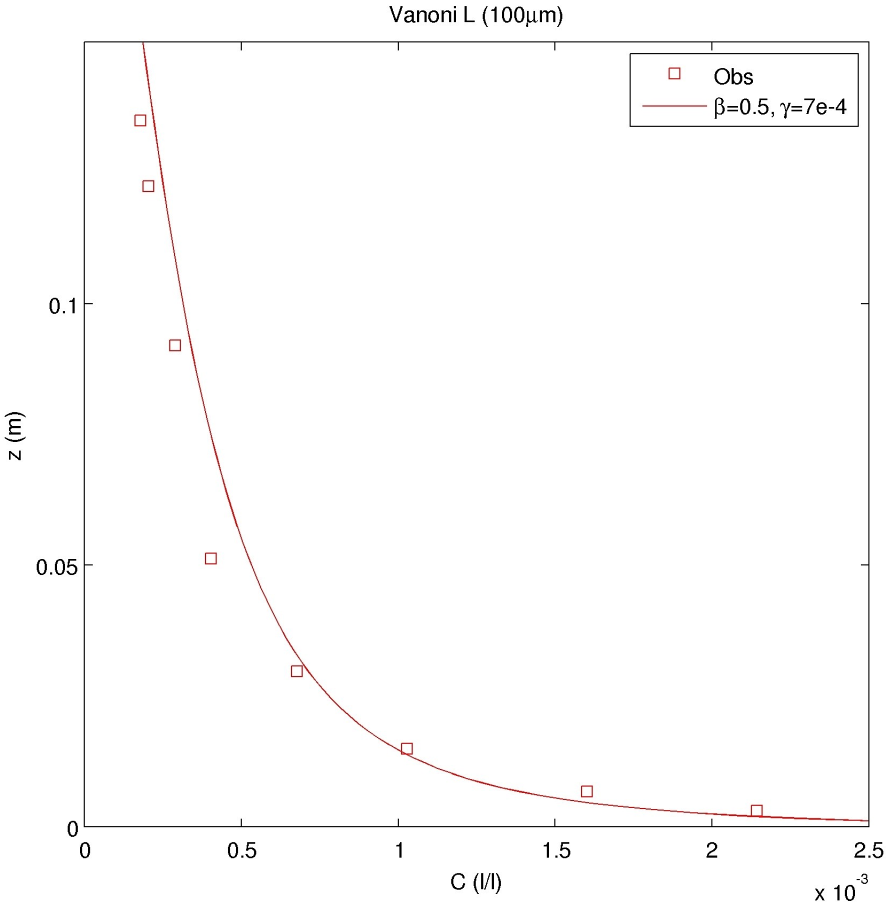
In the literature, resuspension parameter gamma varies over several orders of magnitude (1e-4 – 1e-2)

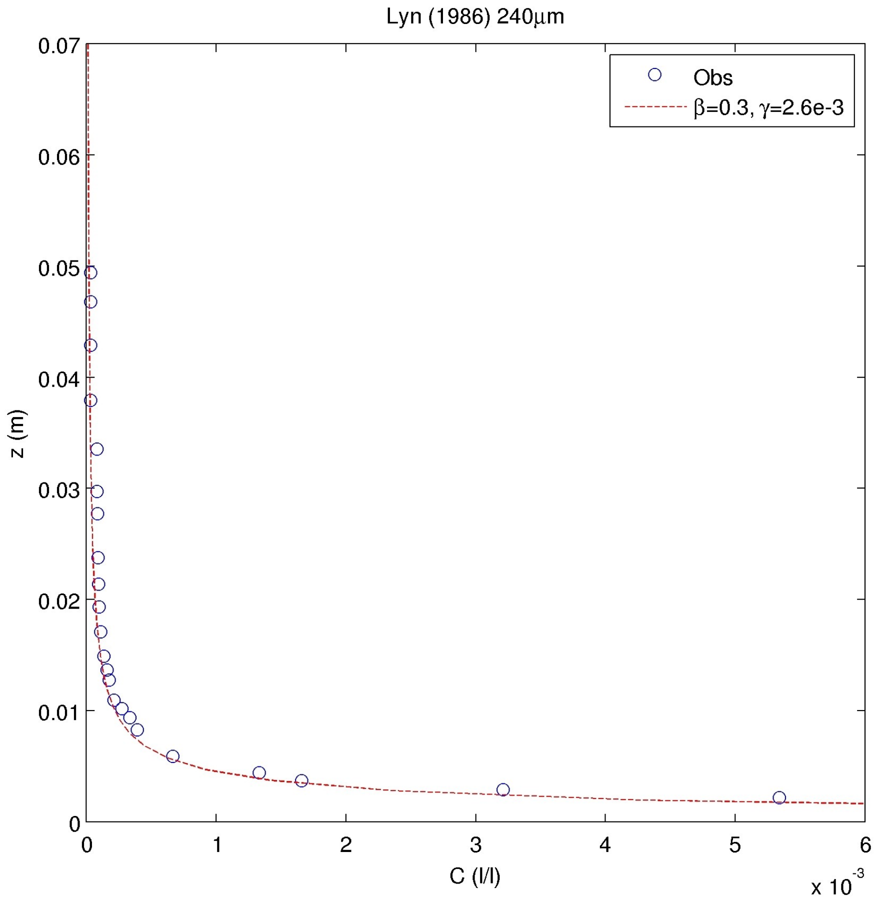
Model tests using similar channel flow and sediment concentration profile data from Vanoni (1940) and Lyn (1986)

Moderate- to well-sorted sand beds (63 – 500 microns), forced with measured distributions

Good agreement with observed C-profiles.

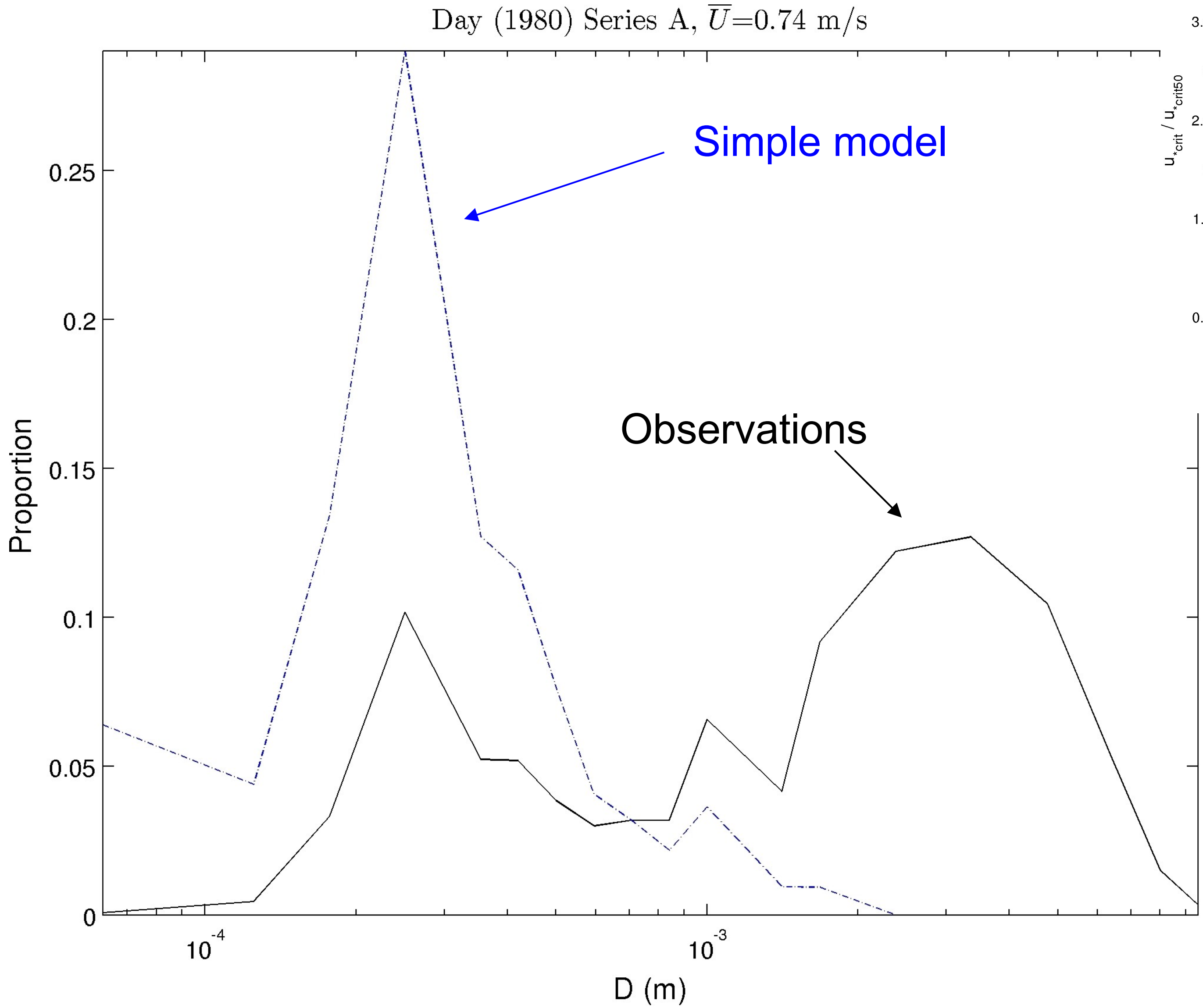
Suggested gamma increased with D50. So decided to use high gamma (1e-2) for Day (1980) data set

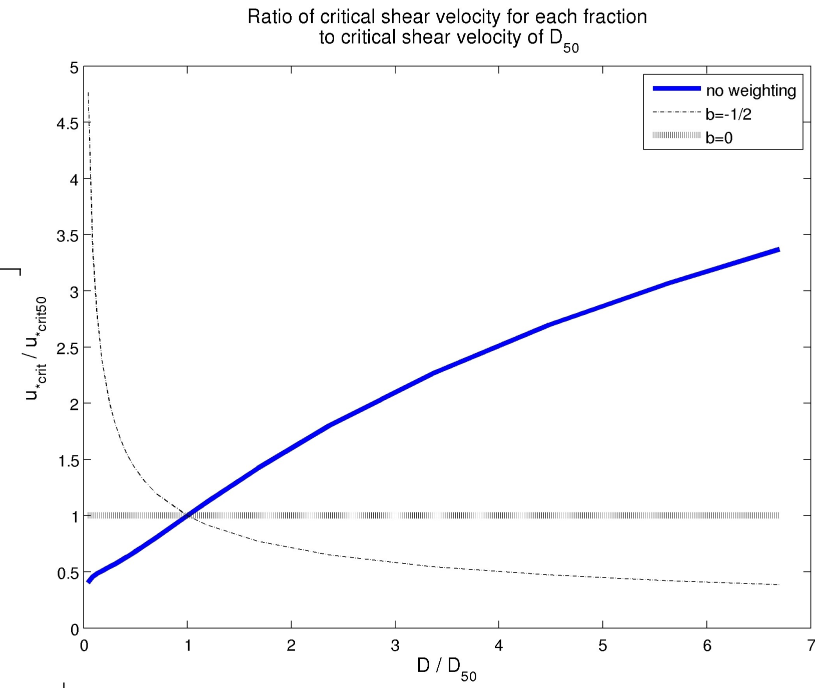




Simple Model - Observation match

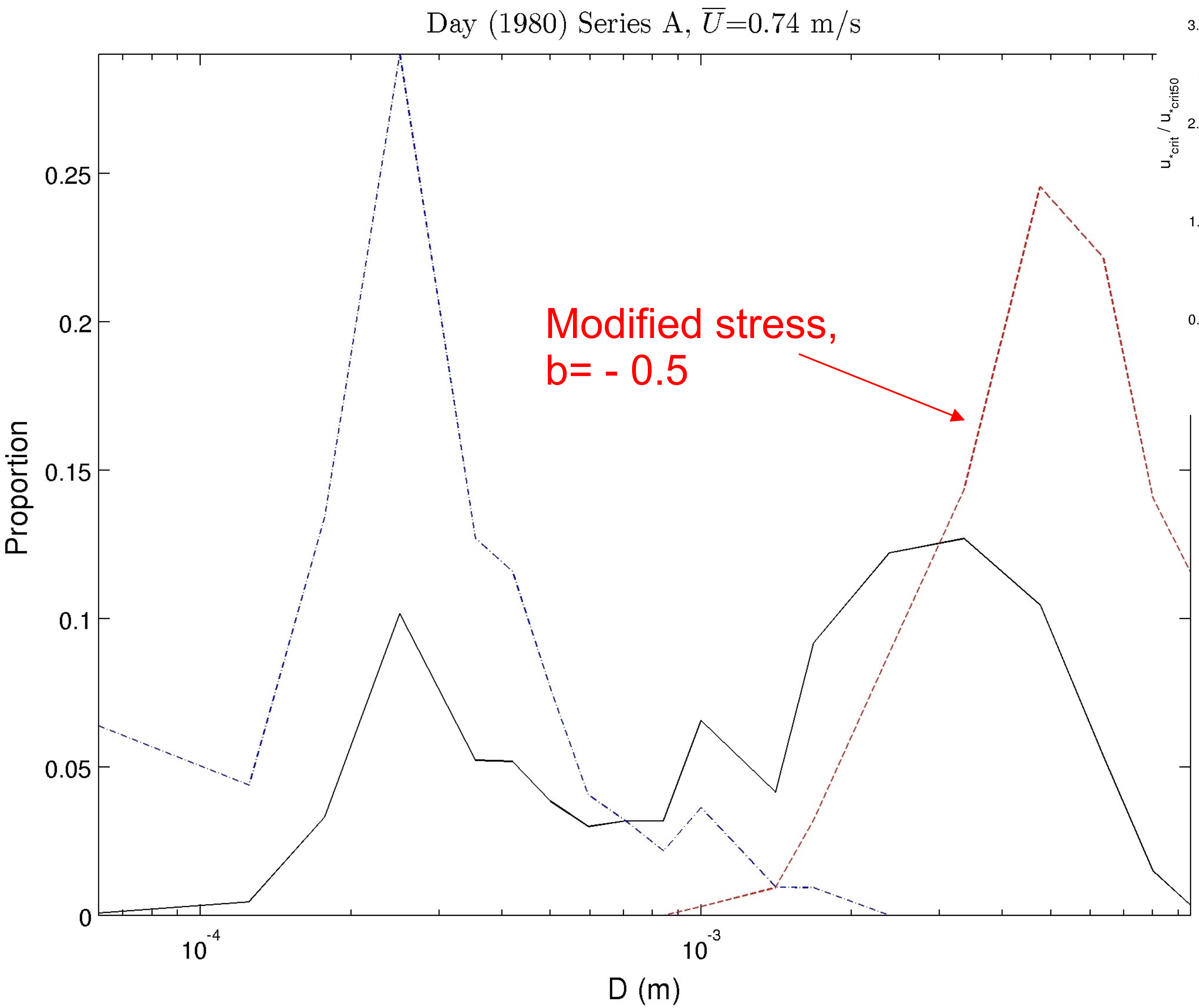
1. DISTRIBUTION HAS NO EFFECT:

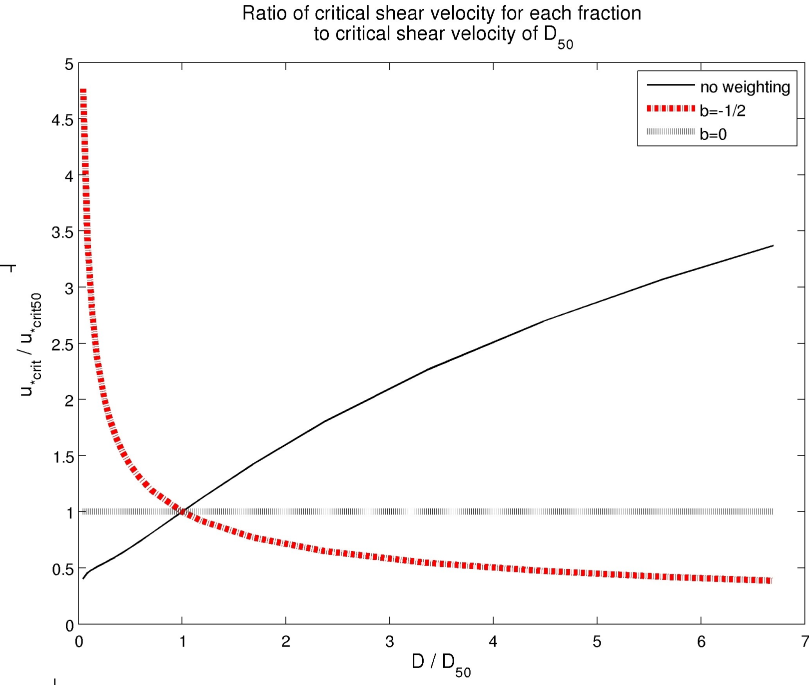




Modified Model - Observation match

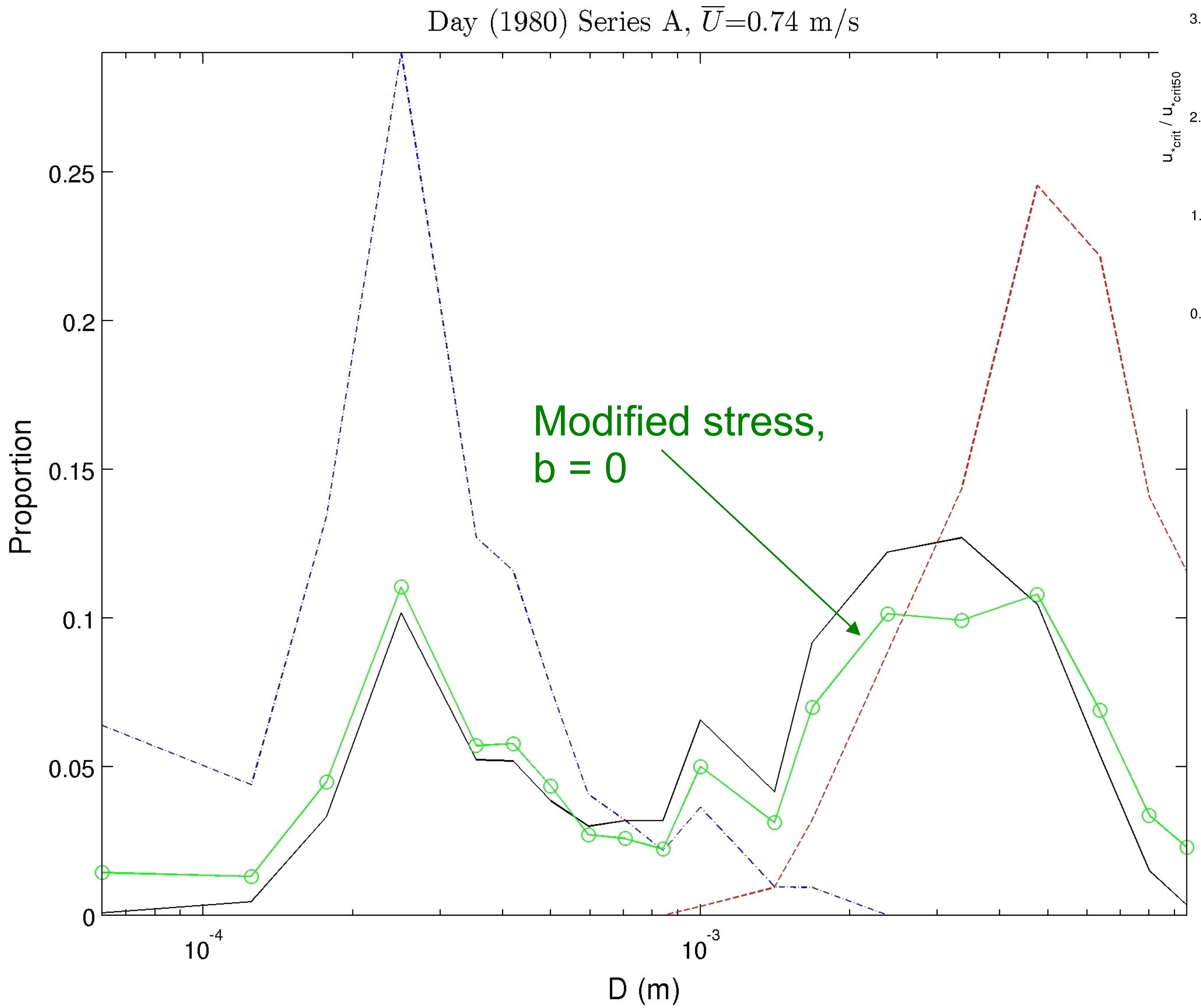
2. DISTRIBUTION 'REVERSES ENTRAINABILITY':

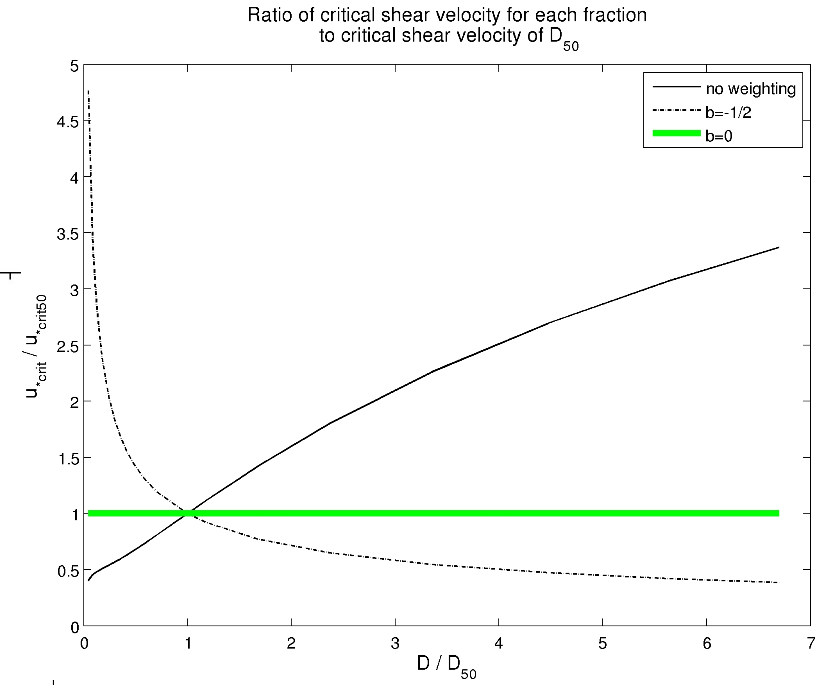




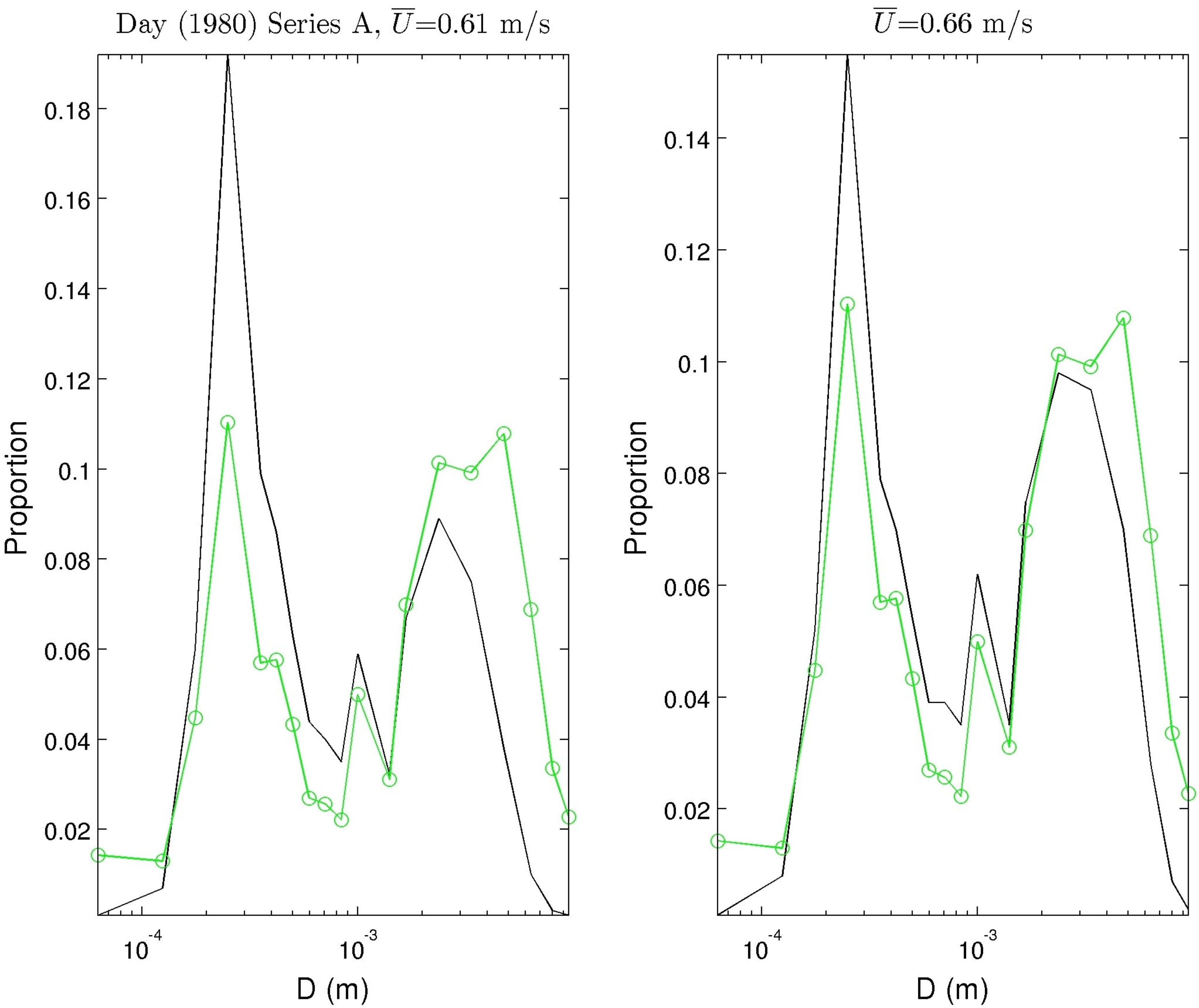
Modified Model - Observation match

3. DISTRIBUTION MEANS GRAINS BECOME EQUALLY ENTRAINABLE





Also works well at velocities closer to D50 critical threshold ...



Summary

We examined the mobilization of a mixed sediment bed in steady flows

The results suggest that relative size effects exactly balance the difference in mass between different fractions, or 'equal mobility'

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