Estimating Nearshore Berm Deflation Using Longshore Transport Equations

Brian McFall, Douglas Krafft, Rachel Bain

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Introduction

- Sediment placed in the nearshore either for beach nourishment or to dissipate wave energy.

- Considerable attention has been given to *whether* the placed sediment will be mobile (*e.g.,* McLellan *et al.*, 1990; Hands and Allison, 1991; Ahren and Hands, 1998; McFall *et al*., 2016; Priestas *et al*., 2019).

- Less consideration of the rate at which the placed sediment will move.

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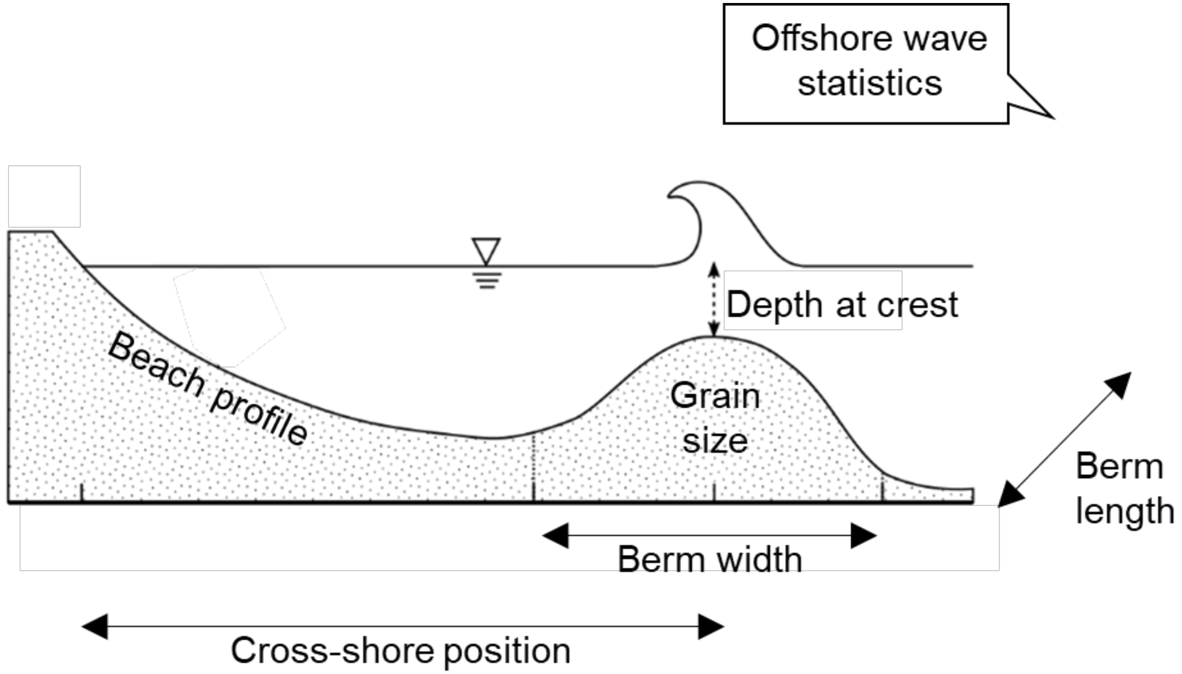
- **Project goal:** to evaluate whether various transport equations (longshore or cross-shore) are useful for generating order-of-magnitude predictions of the nearshore berm deflation rate.

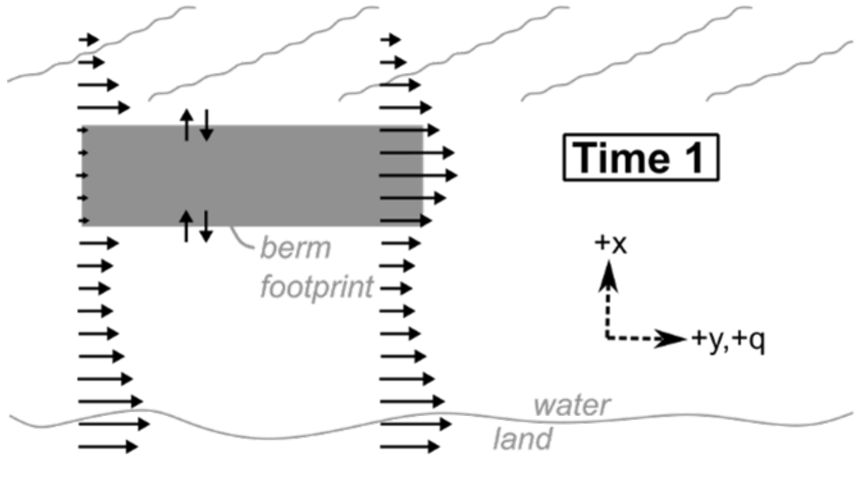
We seek a straightforward calculation method that can run quickly on a personal computer and which is based on easy-to-estimate design parameters.

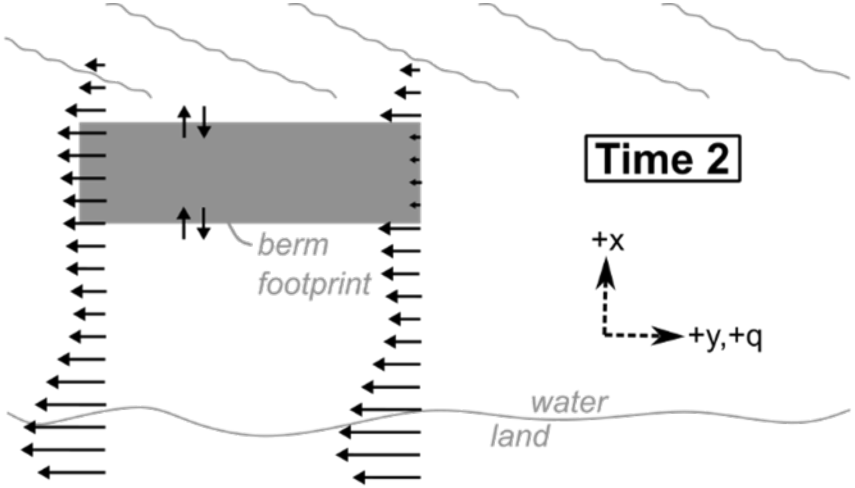


Conceptual model: berm deflation via longshore transport

Experimental and field studies suggest longshore transport may be the dominant mechanism of berm deflation (*e.g.*, Hoekstra *et* al., 1996; Smith *et al.*, 2009; Bryant and McFall, 2016)

- Longshore transport assumed to exclusively remove sediment from the berm.
- Net cross-shore transport assumed negligible.
- The berm's geometrical parameters (cross-shore position, length, depth at crest, etc.) are assumed constant in time.





Longshore transport computation

CERC equation:

$$Q = \frac{K\rho_w g^{0.5} H_b^{2.5}}{16\gamma_b^{0.5}(\rho_s - \rho_w)(1-n)} \sin 2\alpha_b$$

where

Q	Longshore volumetric transport rate
K	CERC coefficient
H_b	Significant wave height at breaking
γ_b	Breaker index, assumed to equal 0.78
α_b	Breaker angle
ρ_w , ρ_s	Density of water and sediment
n	Porosity

Wave parameters including H_b and α_b are derived from WIS hindcast data over the period of interest.

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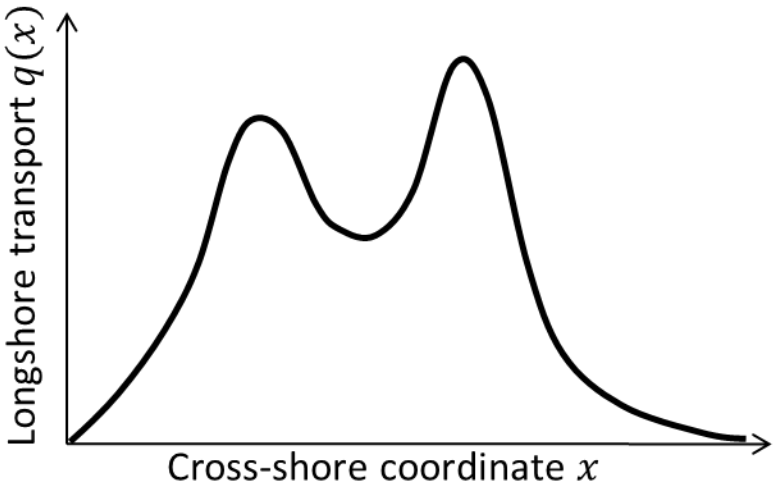
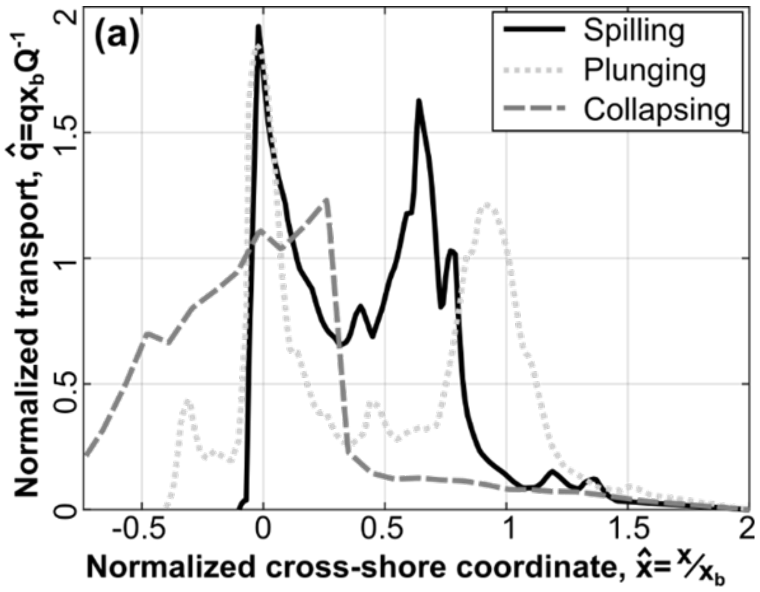


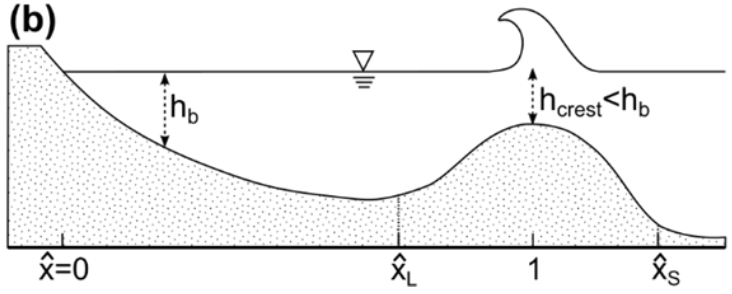
Recall that $Q = \int_{\forall x} q(x)dx$

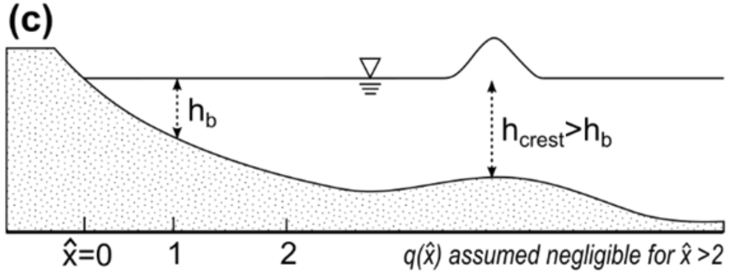
Therefore $Q_{berm} = \beta Q$ for some unknown $0 < \beta < 1$.

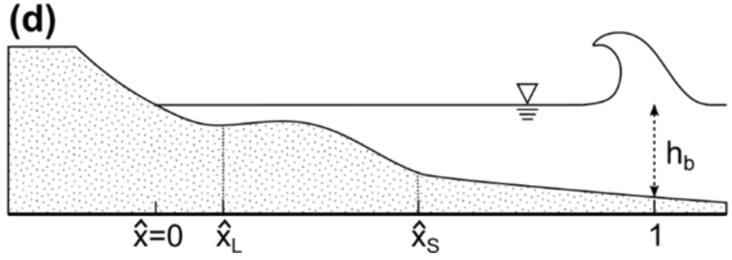
Longshore transport computation

Fraction of Q contributing to berm deflation is based on literature-reported $q(x)$ profiles and the berm's position in nondimensional space.









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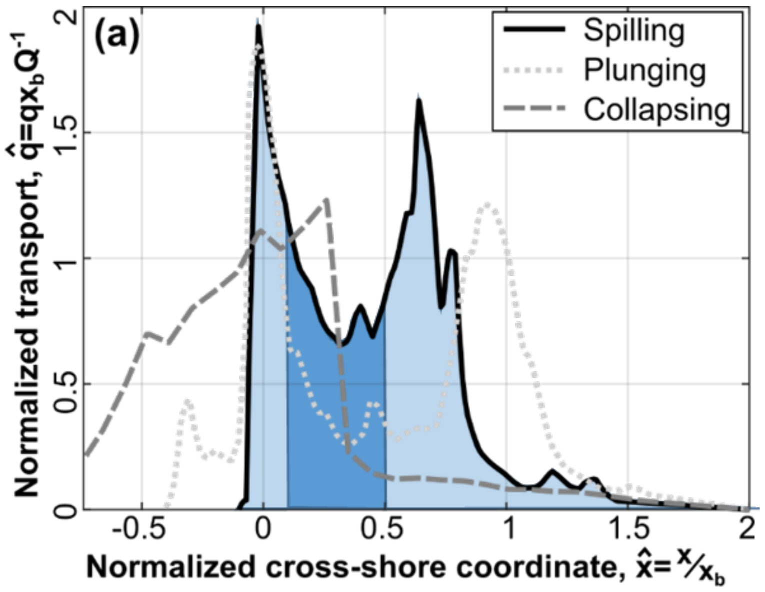
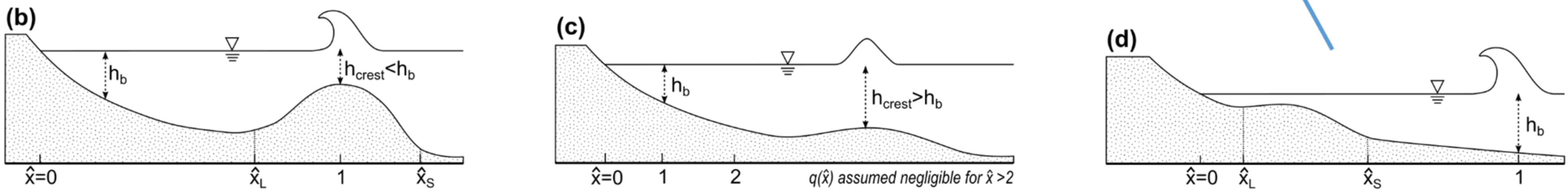




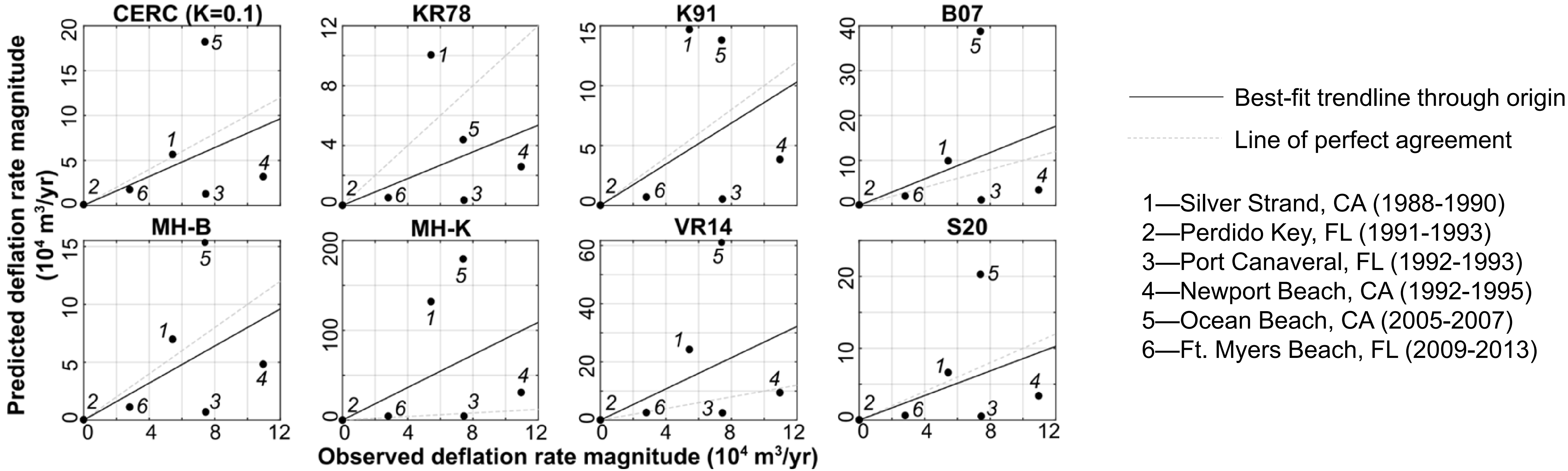
Longshore transport computation

Equation	Parameters influencing longshore transport
CERC equation (constant K)	Depth at breaking
Kamphuis and Readshaw (1978) CERC adaptation	Depth at breaking, wavelength, beach slope (linear)
Kamphuis (1991) equation	Grain size, period, beach slope (linear)
Mil-Homens et al. (2013) modification of Kamphuis (1991)	Grain size, period, beach slope (linear)
Bayram et al. (2007) equation	Depth at breaking, grain size, period, beach profile (nonlinear), friction coefficient
Mil-Homens et al. (2013) modification of Bayram et al. (2007)	Depth at breaking, grain size, wavelength, beach profile (nonlinear), friction coefficient
Van Rijn (2014) equation	Grain size, wavelength, beach slope (linear)
Shaeri et al. (2020) equation	Grain size, wavelength

NOTE: All equations depend on water and sediment density, sediment porosity, breaker angle, and breaker height

Results

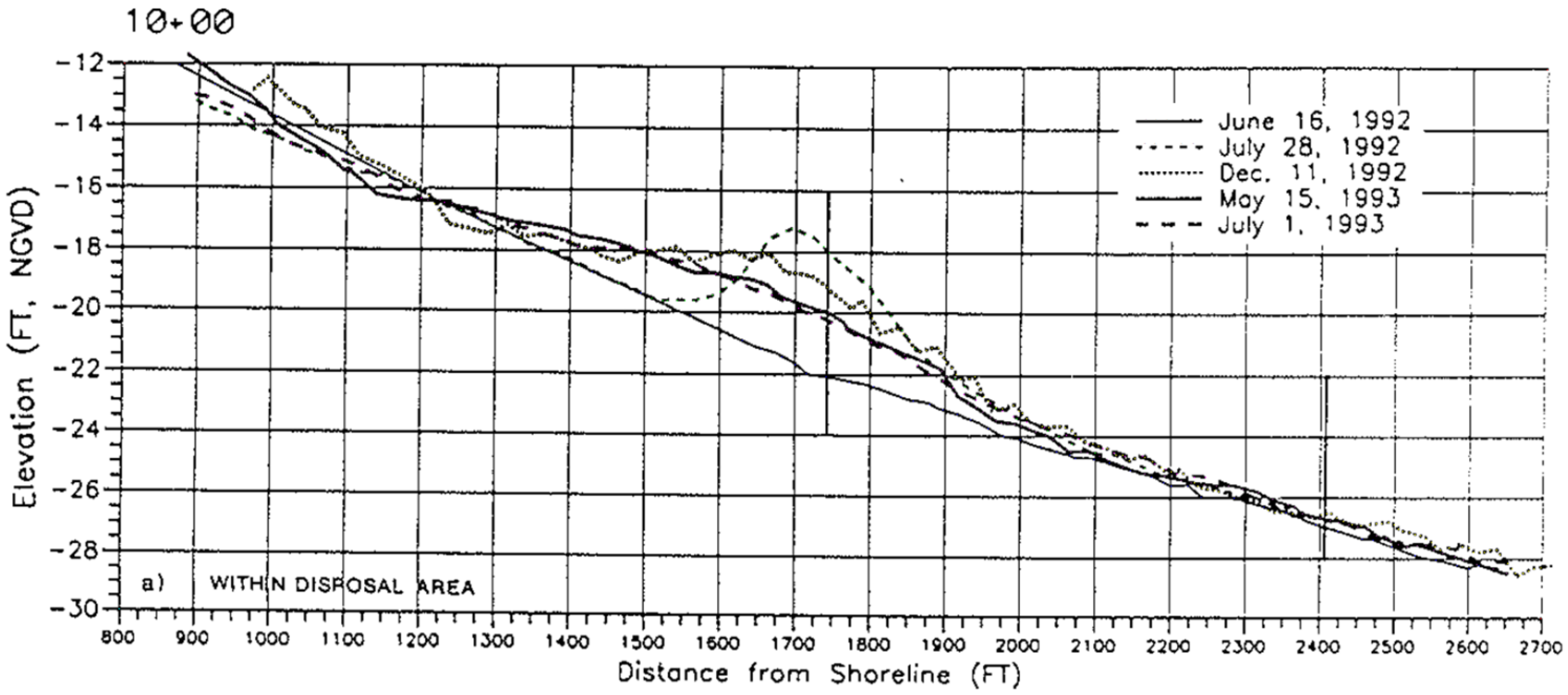
	CERC (K=0.1)	KR78	K91	B07
Max. error:	146%	95%	171%	424%
R^2 =	0.09	-0.001	0.04	0.06



	MH-B	MH-K	VR14	S20
Max. error:	110%	2335%	734%	174%
R^2 =	0.17	0.05	0.08	0.10

Can we justify ignoring cross-shore transport?

Cross-shore profiles of the Port Canaveral berm through time (Bodge, 1994)



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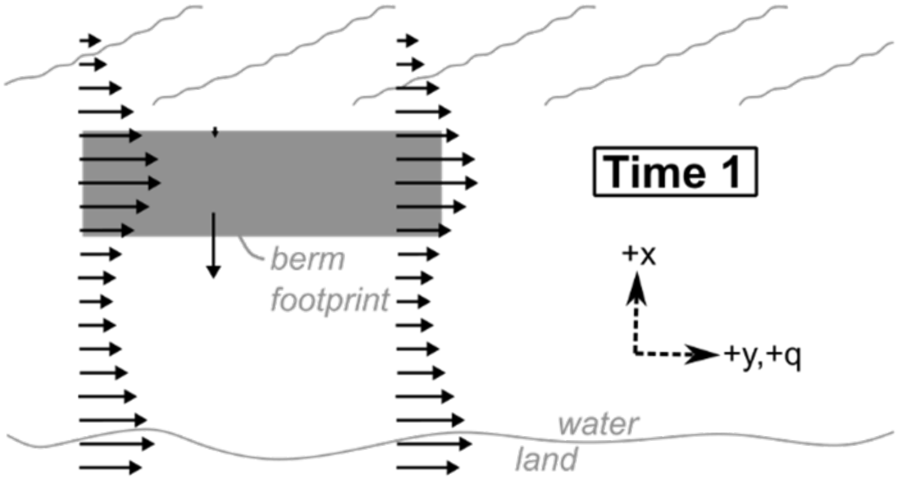
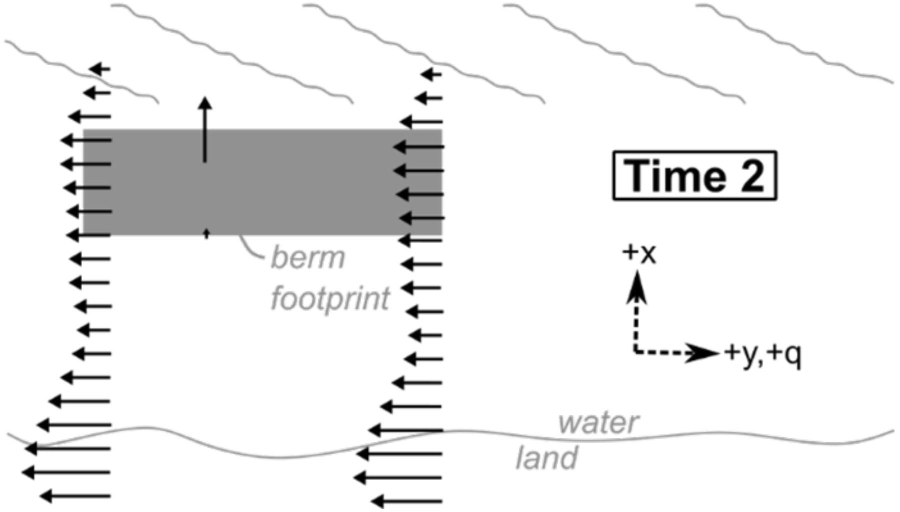


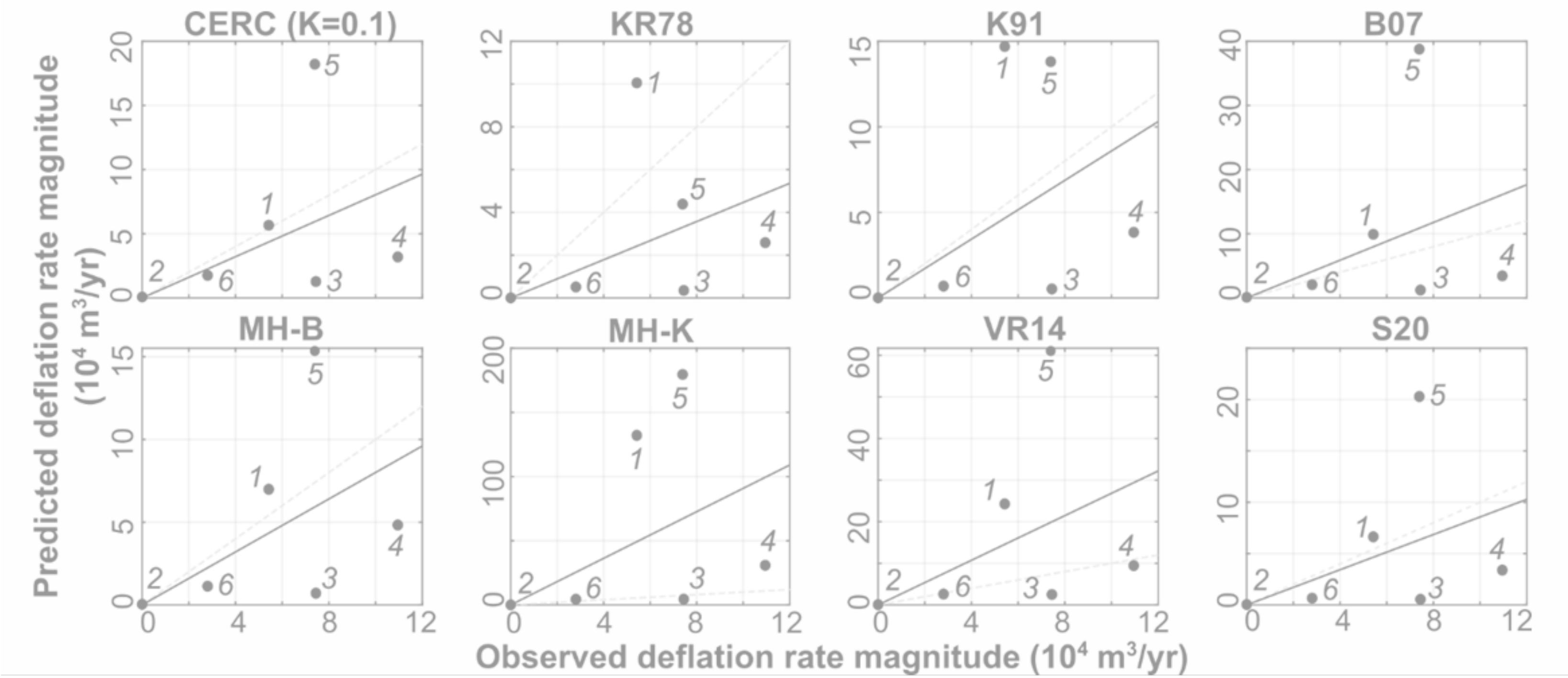


Cross-shore transport computation

Equation	Description
Douglass (1995) equation	***Key idea: wave orbital velocity asymmetry drives cross-shore sediment transport*** ➢ Calculated by applying Stoke's second order wave theory to the Bailard and Inman (1981) bedload transport equation ➢ *Distinctive parameters:* porosity, friction coefficient, transport efficiency coefficient, angle of internal friction
Ortiz and Ashton (2015) equation	***Key idea: cross-shore sediment transport is generated by wave orbital stirring, Longuet-Higgins streaming velocity, and wave asymmetry*** ➢ Calculated by applying Stoke's second order wave theory to Bowen's (1980) transport equation ➢ *Distinctive parameters:* grain size, friction coefficient, transport efficiency coefficient

NOTE: All equations depend on water and sediment density, wave height, wave period, water depth above berm, bed slope, berm length in the longshore direction

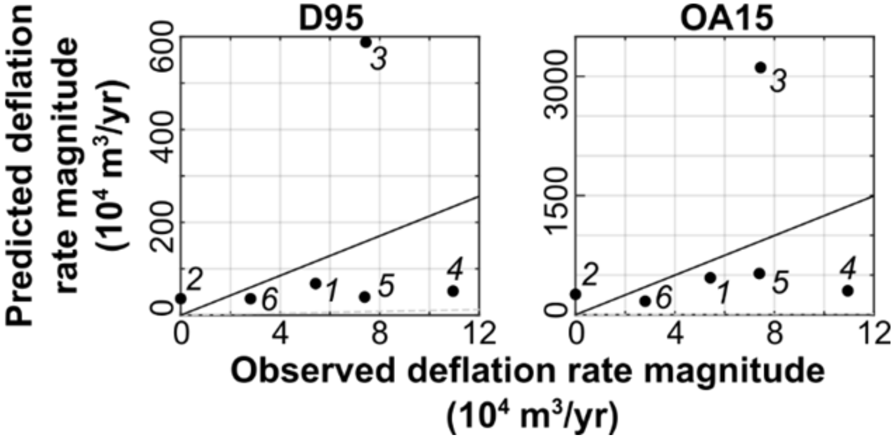
Results



Best-fit trendline through origin

Line of perfect agreement

1—Silver Strand, CA (1988-1990)
2—Perdido Key, FL (1991-1993)
3—Port Canaveral, FL (1992-1993)
4—Newport Beach, CA (1992-1995)
5—Ocean Beach, CA (2005-2007)
6—Ft. Myers Beach, FL (2009-2013)



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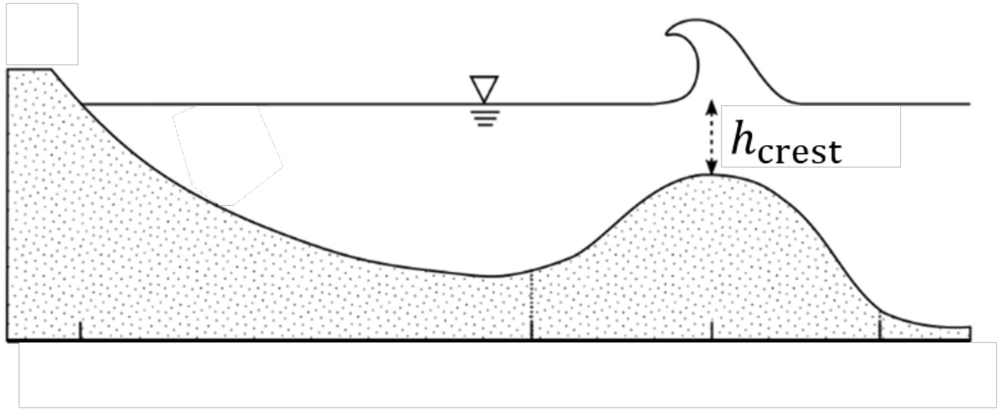


Douglass (1995) equation:

$$Q = \frac{9\pi^2}{64}\frac{\rho_w g C_f \varepsilon_b (\tan\phi - \tan\beta)}{(\rho_s - \rho_w) a' \tan^2\phi}\frac{H^4 T}{L^2}\underbrace{\operatorname{sech}^2\left(\frac{2\pi h}{L}\right)}\underbrace{\operatorname{csch}^4\left(\frac{2\pi h}{L}\right)}$$

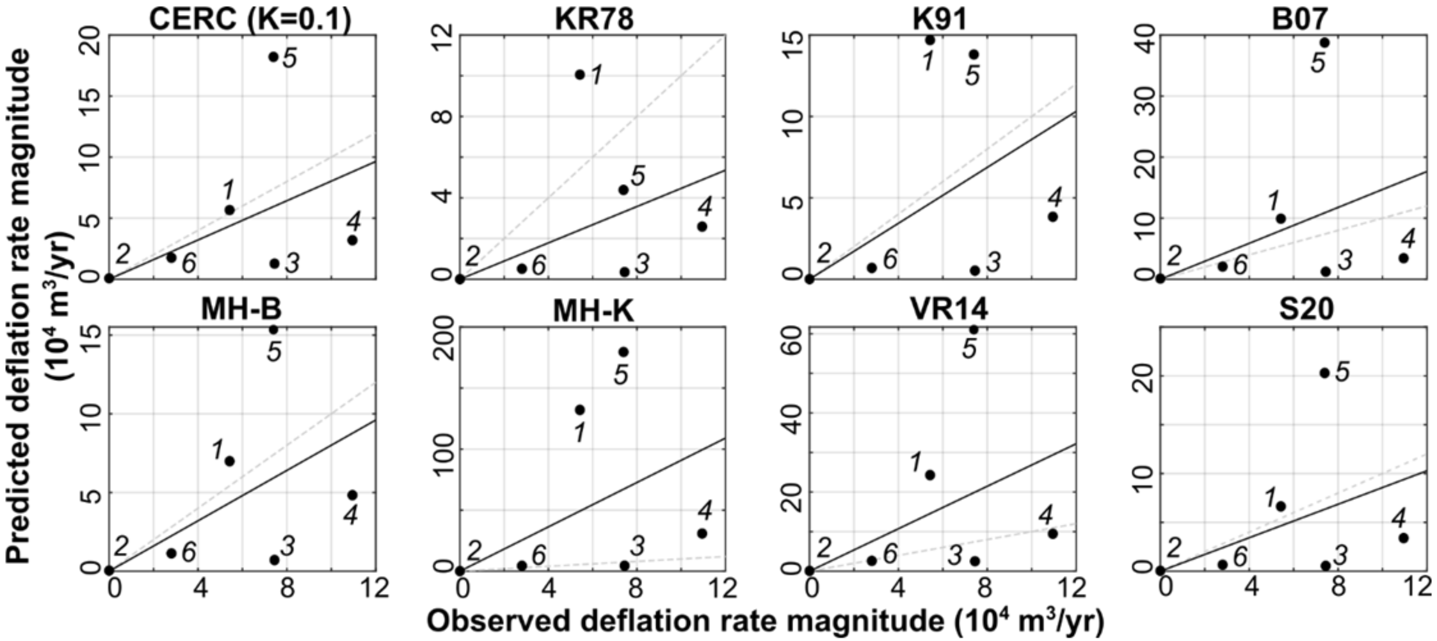
Under physically realistic assumptions, both terms decrease as h increases.

↓

Over-estimation of Q if we take $h = h_{\text{crest}}$ = constant (in space and time)

Next steps

Longshore transport equations:



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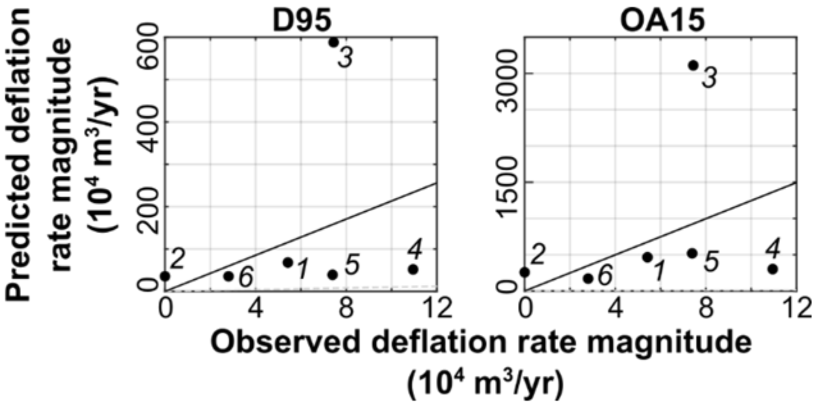

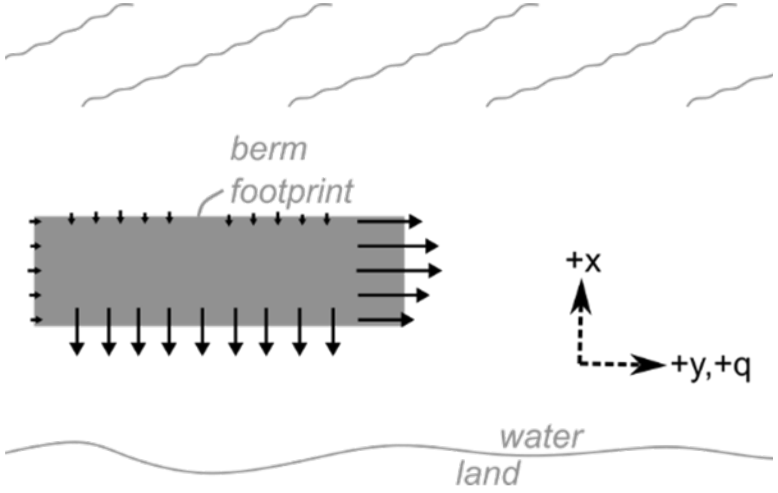

?

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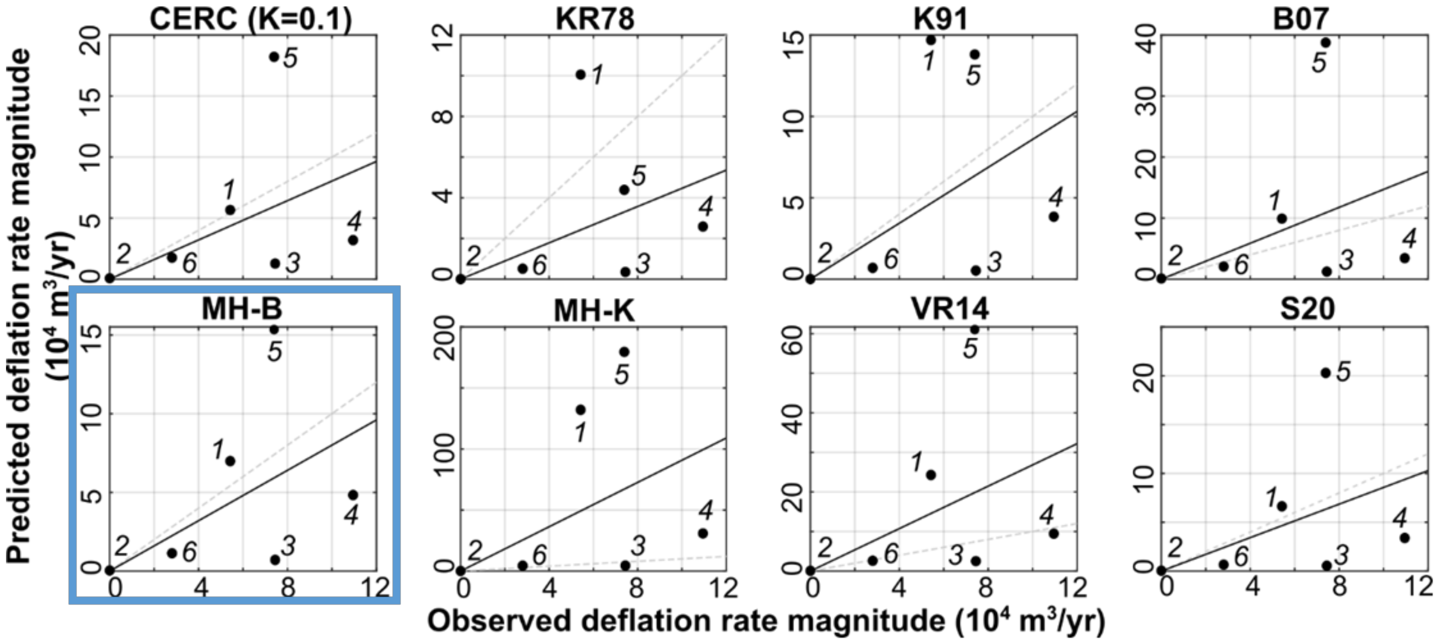

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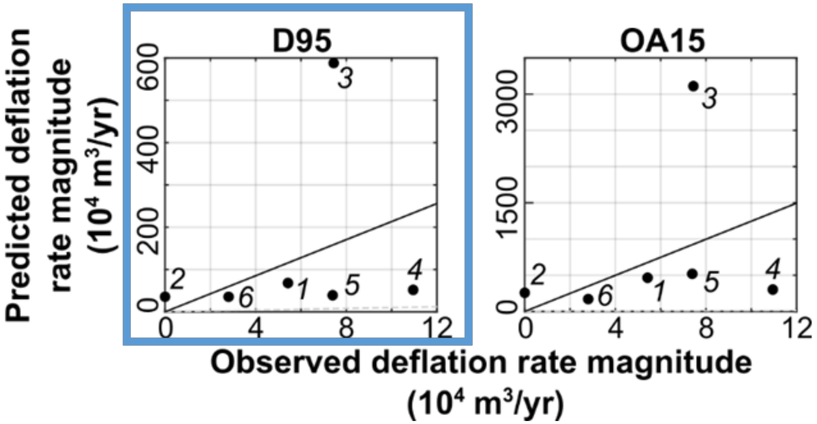
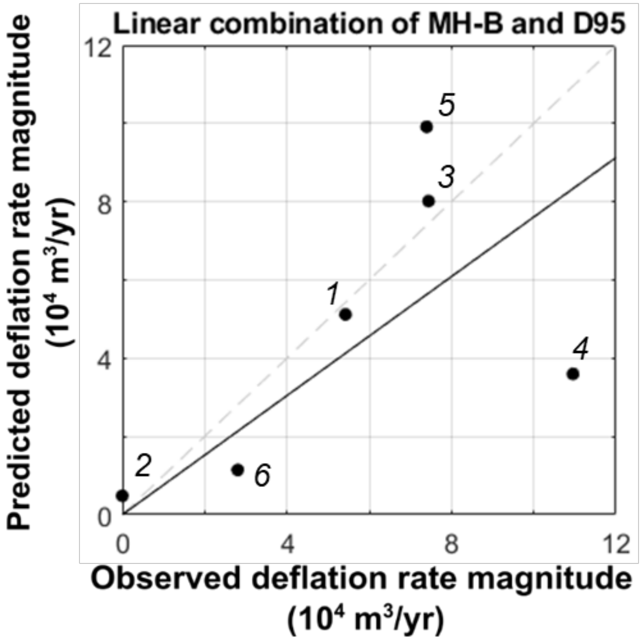


Best-fit linear combination of longshore and cross-shore:

$$Q_{\text{total}} = 0.61Q_{\text{MHB}} + 0.01Q_{\text{D95}}$$

Max. error: 67%; $R^2 = 0.31$



Drawback: entirely statistical solution—no physical basis for the coefficients.

Next steps

- Alternative cross-shore transport formulations? ← **Will it make a difference?**

- Vary berm's geometrical parameters through time? ← **Inconsistent with stated project goals?**

- …others?