Nearshore Nourishment: Updated methods for predicting nearshore berm deflation rates

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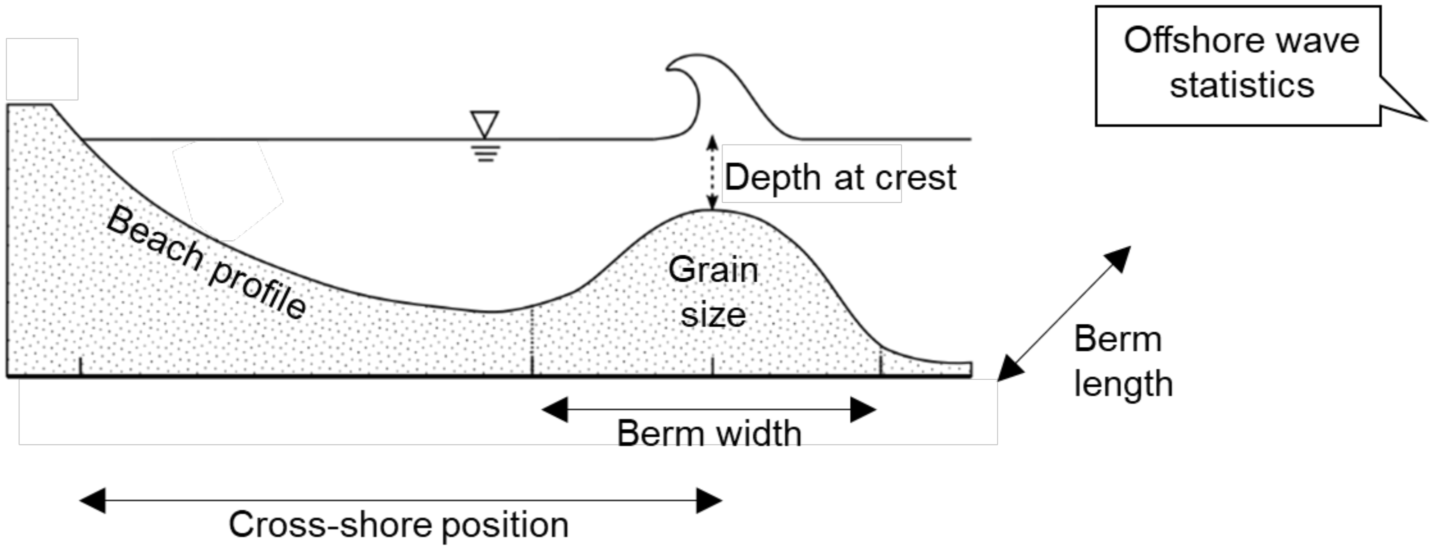
May 11, 2021

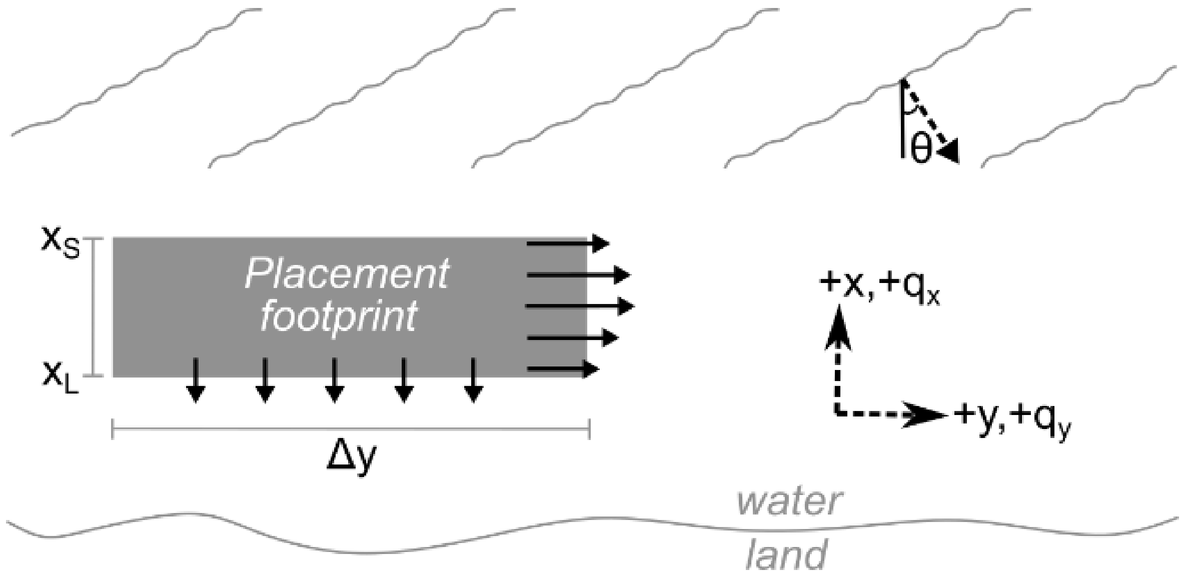
Introduction

- Will sediment placements in the nearshore be mobile? ← Prior studies focus on this question.
- At what rate will placed sediment move? ← Little attempt to evaluate.
- **Project goal is to develop a method for calculating nearshore berm deflation rates which meets the following criteria:**
  - **Order-of-magnitude deflation rate estimates.**
  - **Quick calculations with minimal computational effort.**
  - **Based on easy-to-estimate design parameters.**

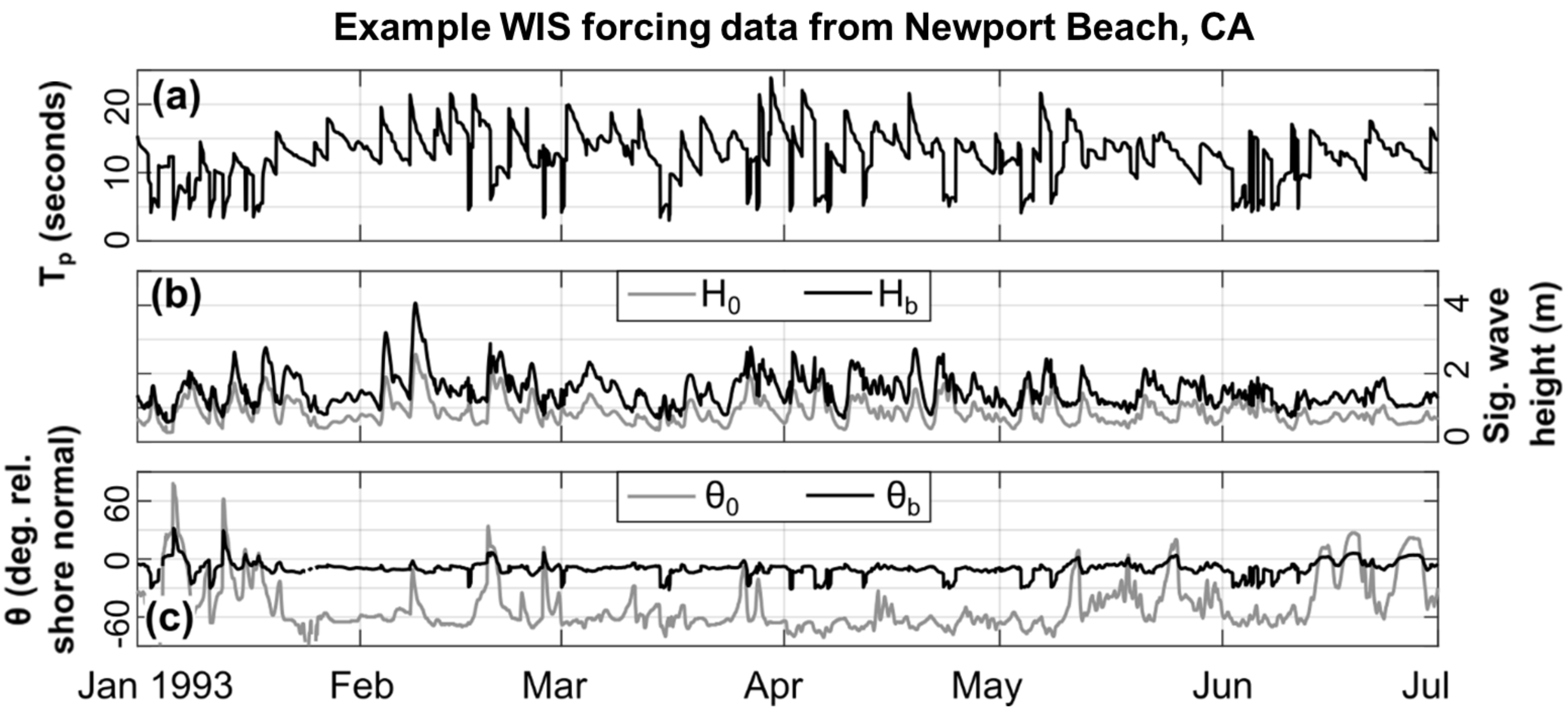


The big picture

- Longshore and cross-shore transport are treated as independent (orthogonal) processes which can be calculated separately and superimposed.
- Nearshore berm "deflation" is defined as the transport of sediment away from the original placement footprint.
- Assume that sediment is exclusively removed from the berm (no "reinflation").
- Berm geometry (cross-shore position, length, depth at crest, *etc.*) are assumed constant in time.
- Wave conditions vary with Δt=1 hour.



The big picture



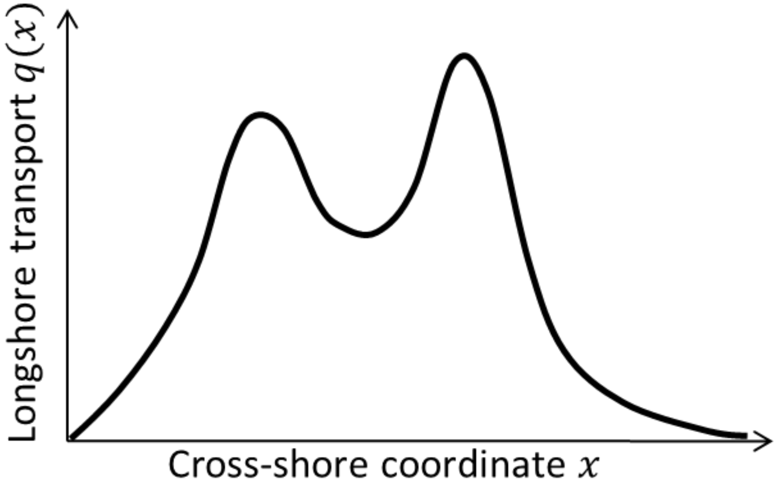
Recap: berm deflation via longshore transport

CERC equation:

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

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
θ_b	Breaker angle
ρ_w , ρ_s	Density of water and sediment
n	Porosity

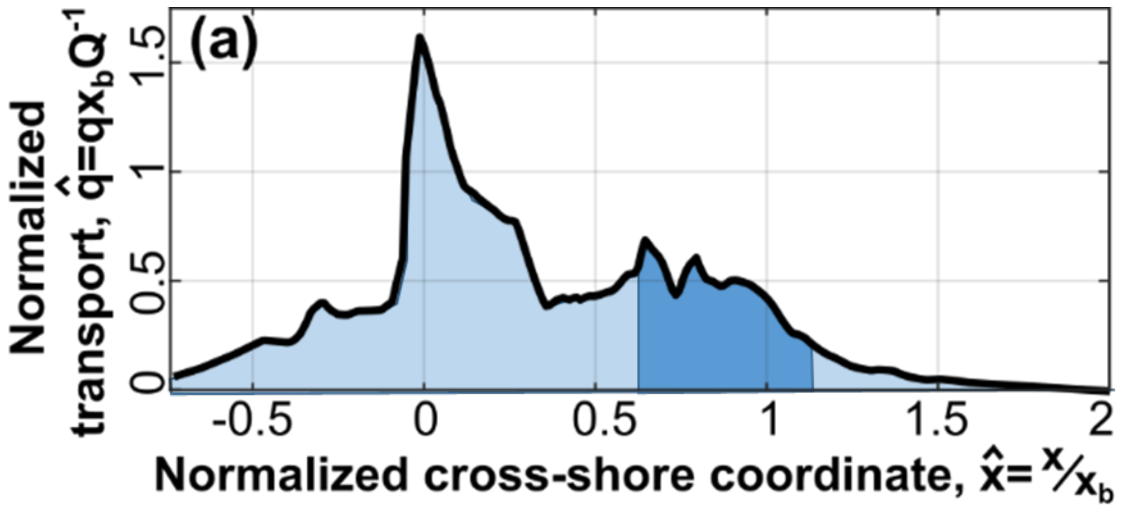


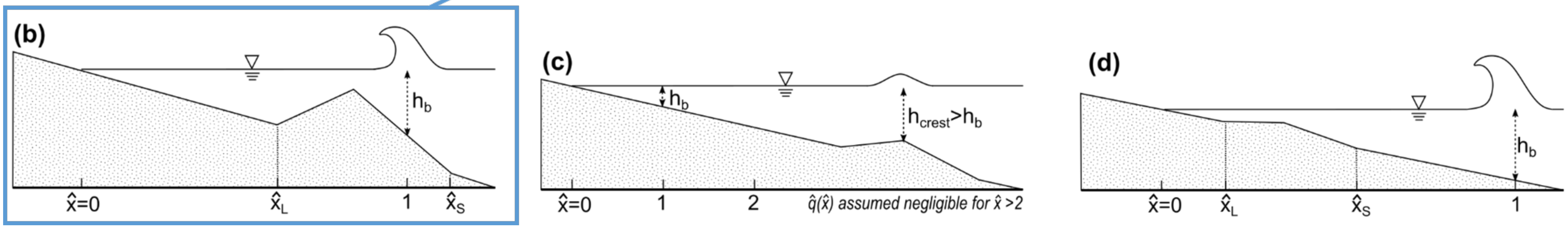
Recall that $Q = \int_{\forall x} q(x)dx$

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

Recap: berm deflation via longshore transport

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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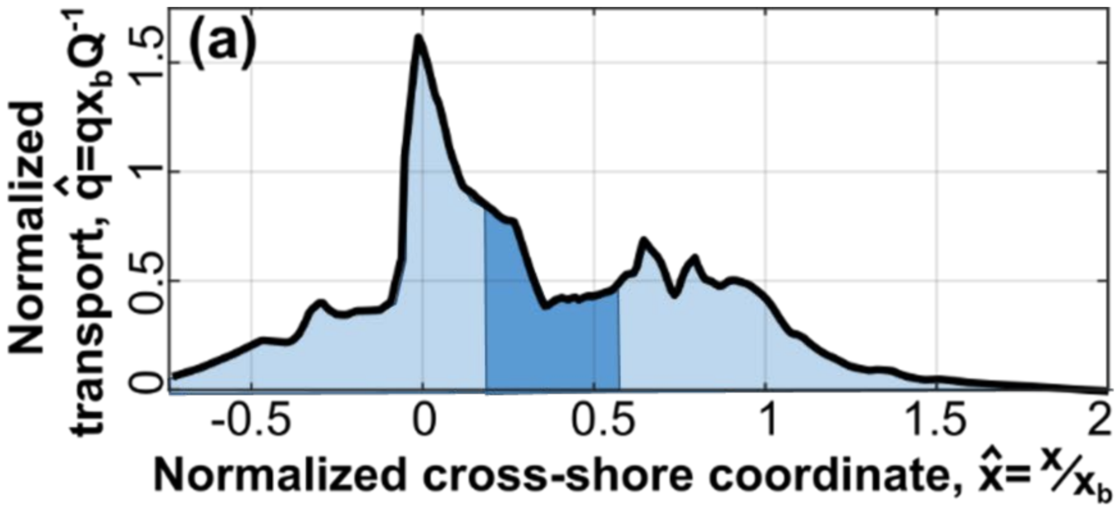

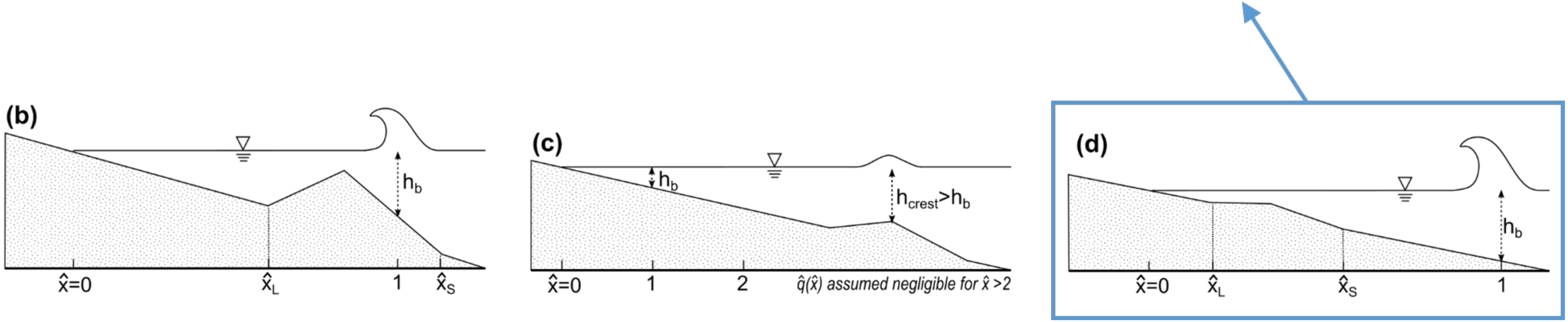

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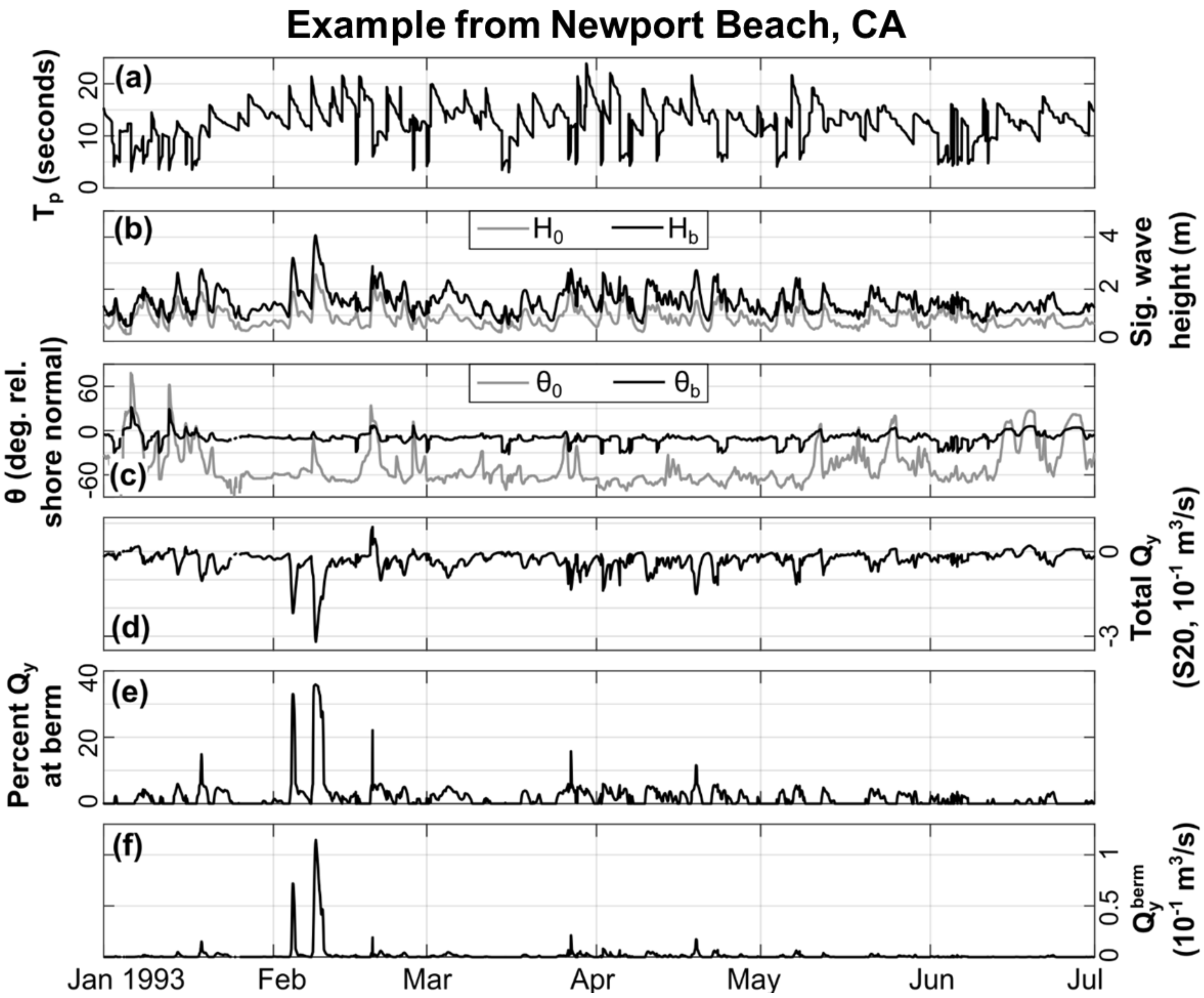


Bulk longshore transport

Scaling value

Longshore deflation rate

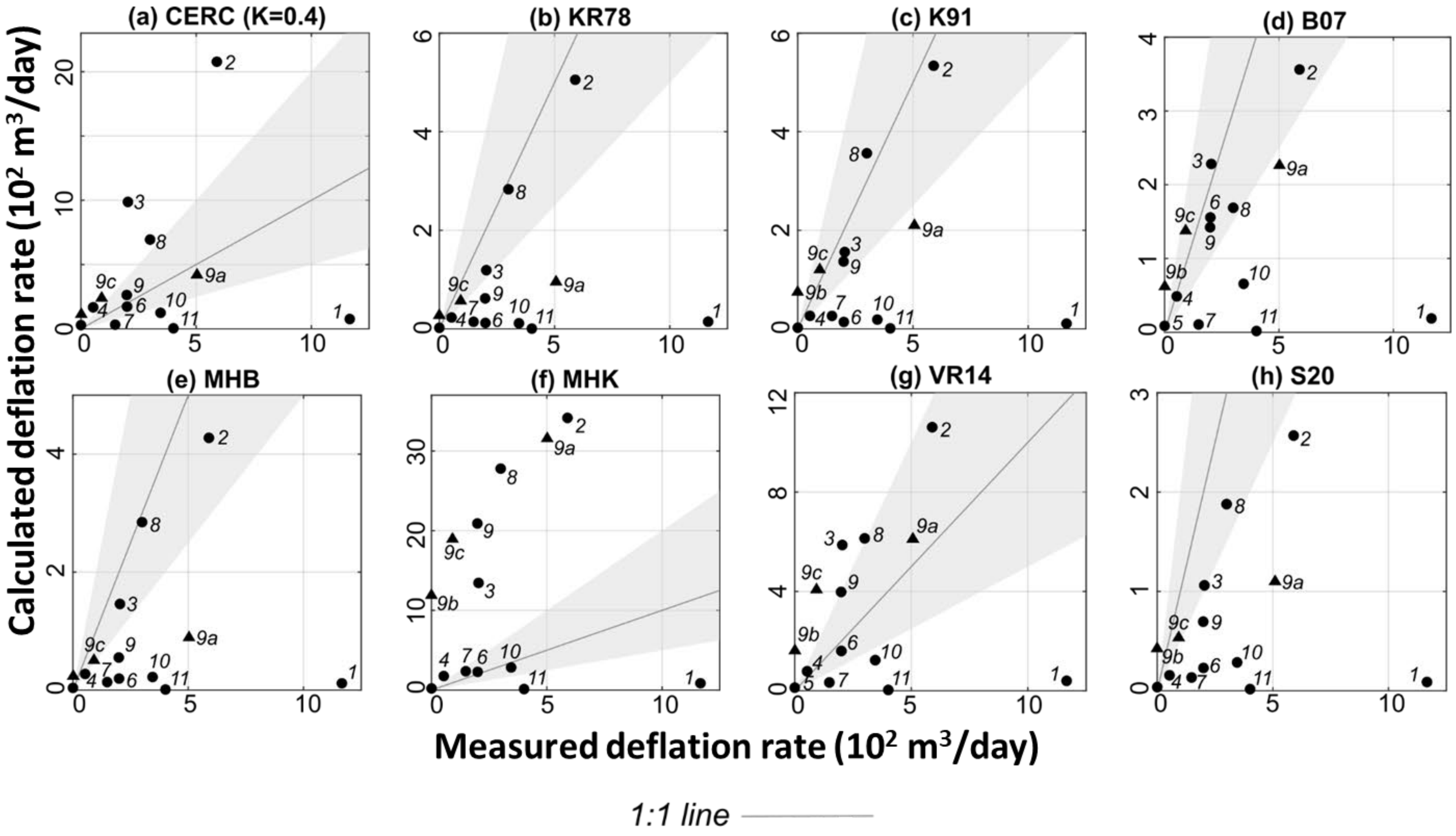
Recap: berm deflation via longshore transport

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

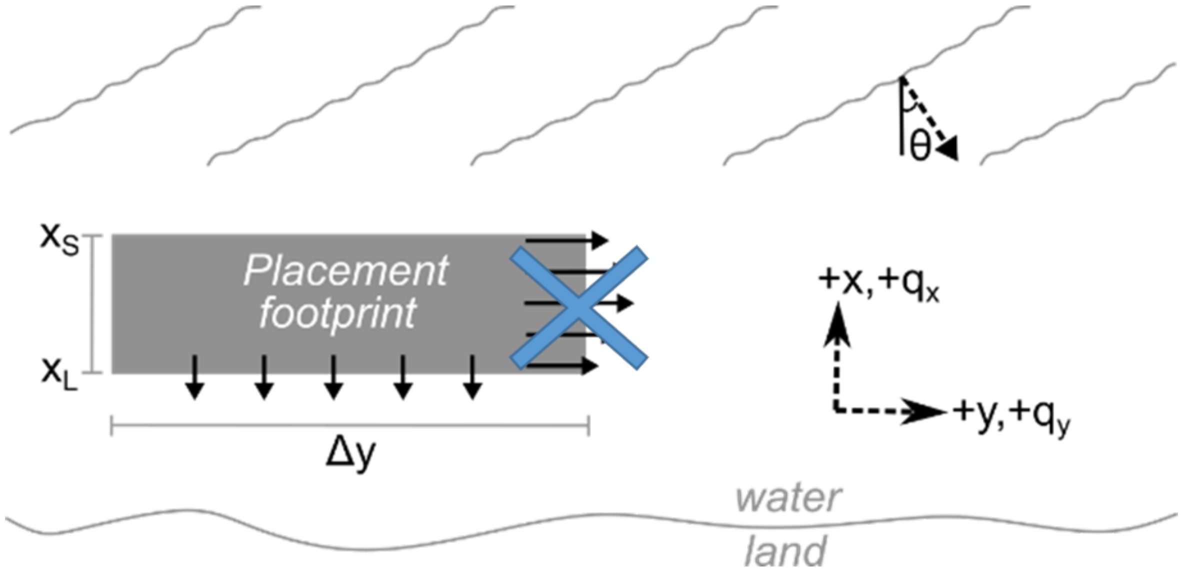
Longshore deflation results

- Most equations display a negative bias (underprediction of transport).



Updated methods: cross-shore transport

- Recall that we are treating longshore and cross-shore transport as independent values which can be calculated separately and superimposed.
- Cross-shore deflation can be directed onshore (pictured) or offshore depending on wave conditions and site geometry.
- Early attempts to calculate a cross-shore deflation rate generated values that were several orders of magnitude too large.
- New cross-shore method from Austin Hudson, Rod Moritz, and Jarod Norton (accepted Technical Note forthcoming in 2021) accurately predicted nearshore berm deflation rates at the Columbia River mouth.



Updated methods: cross-shore transport

Based on Dronkers (2016):

$$Q_{\text{cross}} = \left|\alpha\left[\lambda m\langle|u_w|^3\rangle - \langle|u_w|^2 u_w\rangle(1-\kappa)\right]\right| \cdot \cos(\theta_{\text{crest}})\,\Delta y$$

m=beach profile slope

Critical velocity scaling term (no transport if peak orbital velocity is less than critical velocity)

down-slope transport due to gravity

wave velocity-driven transport

where $\kappa = \min\left({}^{u_{\text{cr}}}/_{u_w^{\max}}, 1\right)$, and α and λ are empirical parameters.

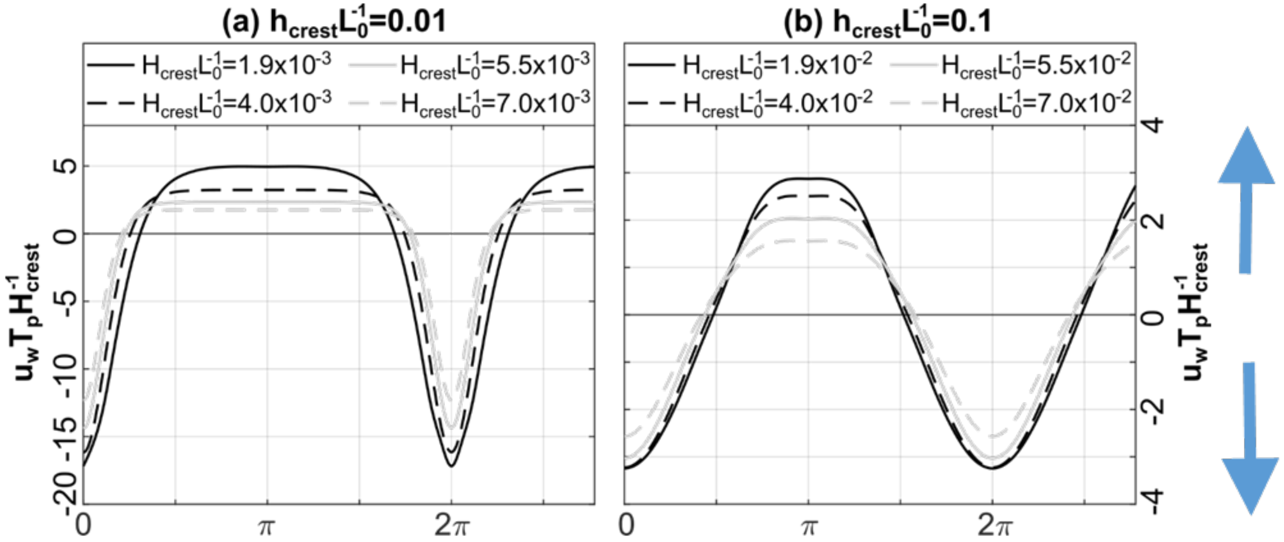
Updated methods: cross-shore transport

Based on Dronkers (2016):

$$Q_{\text{cross}} = \underbrace{\left|\alpha\left[\lambda m\langle|u_w|^3\rangle - \langle|u_w|^2 u_w\rangle(1-\kappa)\right]\right|}_{\text{Unit-width, wave-averaged (mostly) cross-shore transport}} \cdot \underbrace{\cos(\theta_{\text{crest}})}_{\text{Limit to cross-shore component}} \overbrace{\Delta y}^{\text{Alongshore length of placed sediment}}$$

where $\kappa = \min\left({}^{u_{\text{cr}}}/_{u_w^{\max}}, 1\right)$, and α and λ are empirical parameters.

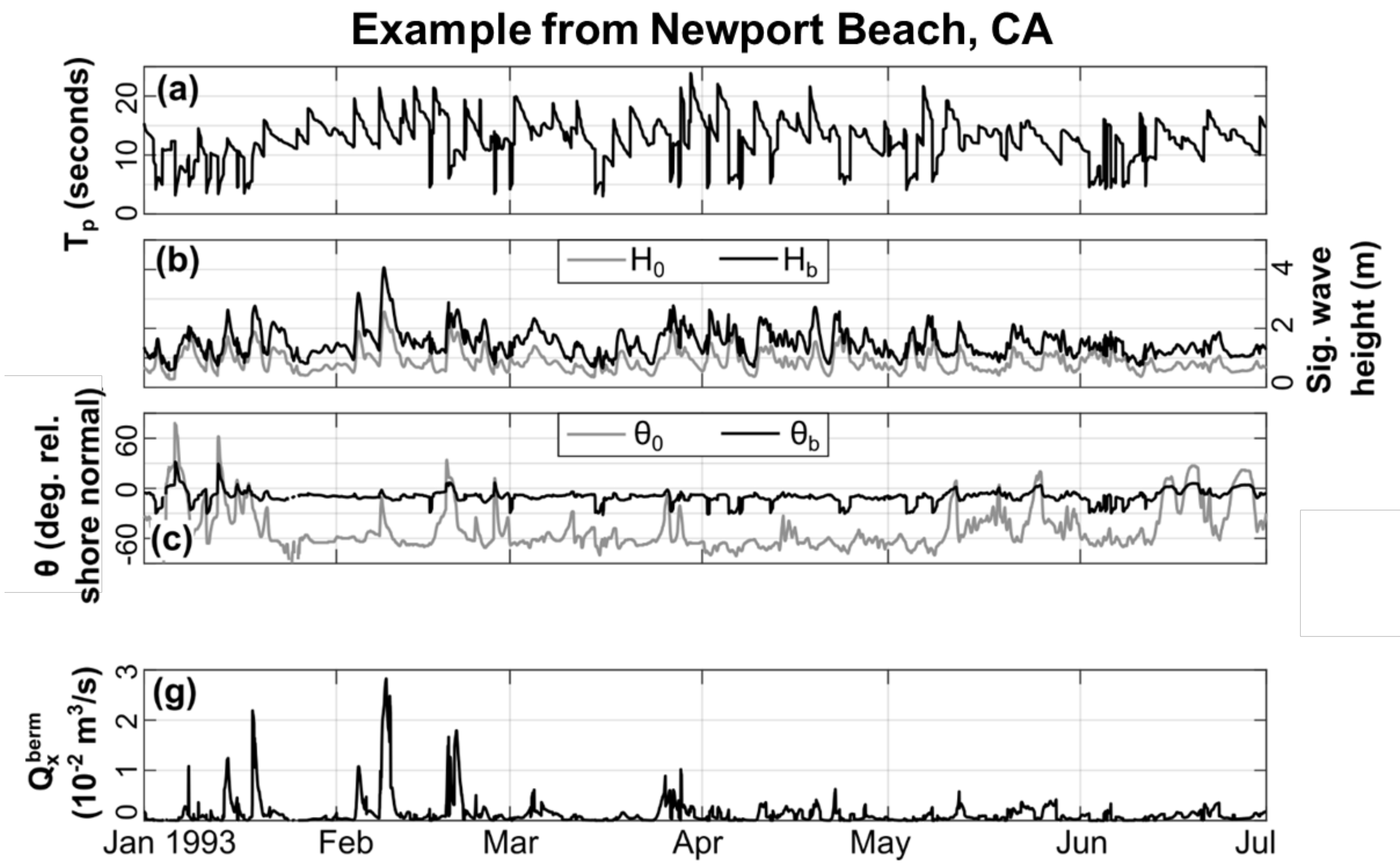
Near-bed velocity u_w is determined from stream-function wave theory based on depth of berm crest, wave height at berm crest, and deep-water wavelength.



Offshore-directed velocity

Onshore-directed velocity

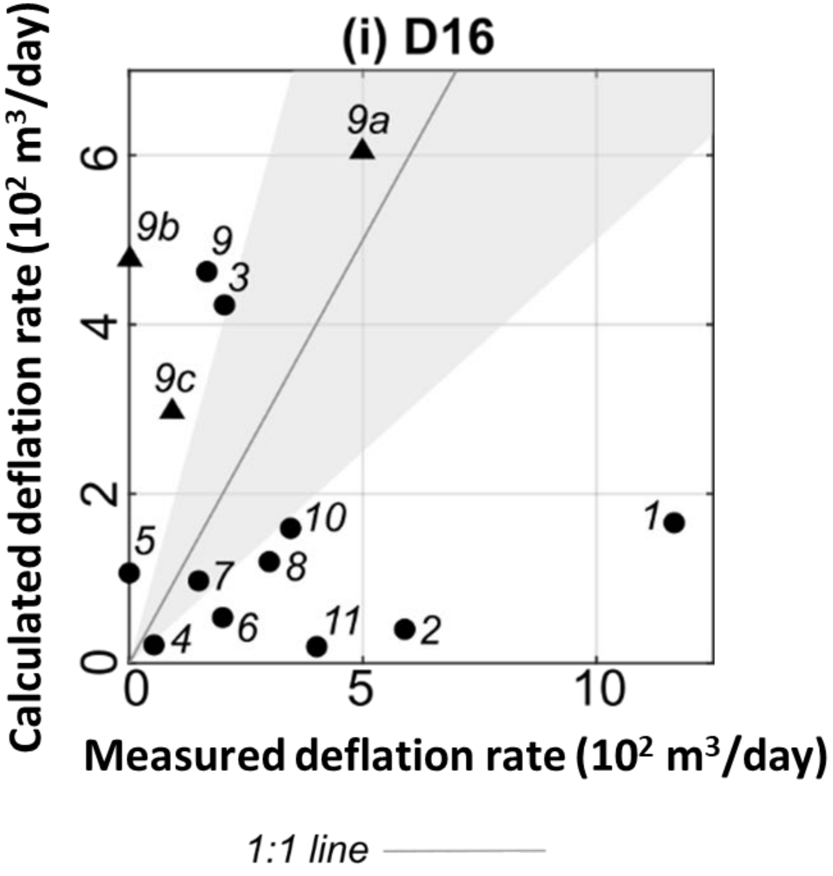
Updated methods: cross-shore transport



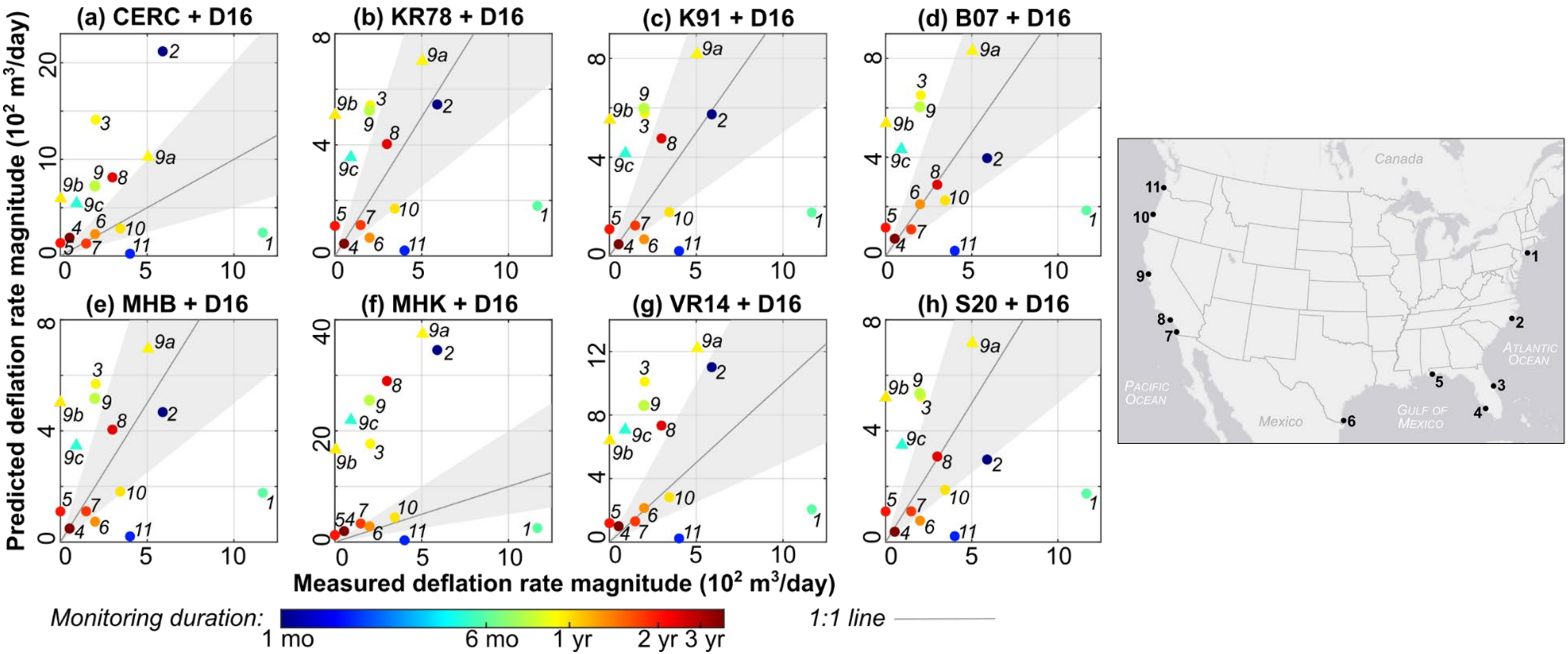
Cross-shore deflation

Cross-shore deflation results

Underprediction at all sites except Port Canaveral (site 3), Perdido Key (site 5), and Ocean Beach (site 9).



Superimposed longshore and cross-shore transport



Conclusions

Best-performing method: Shaeri et al. (2020) longshore transport with Dronkers (2016) cross-shore transport

- Comparatively low bias (-110 m^3/day)
- Comparatively low percent error magnitude (average 72%)
- Low sensitivity to grain size (4% change in calculated value when d_{50} is varied by ±20%)
- Low sensitivity to beach slope (3% change in calculated value when $\Delta z/\Delta x$ is varied by ±0.005)