Notes on the Larson et al. (2016) shoreline change model

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Larson et al. (2016)

The Larson et al. (2016) model was developed to simulate cross-shore transport and the resulting profile response at **decadal** time scales. In contrast with other models described before (e.g. Vitousek et al. (2017), Yates et al. (2009)), the Larson et al. (2016) model explicitly accounts for morphological changes in diverse beach profile features (see Fig. 1 and Table 1). Since the Yates et al. (2009) model neglects geological feedbacks on shoreline evolution, the simulation of morphological features dynamics may be crucial to overcome current limitations on long-time scale shoreline change predictions.

The Larson et al. (2016) model employs equations of both sediment transport and sediment volume conservation based on physics and empirical observations. The modules of the model describes: 1) cliff/dune erosion and overwash, 2) bar-berm material exchange, and 3) wind-blown sand transport. The application of the Larson et al. (2016) model to diverse study sites is described in a companion paper (Palalane et al., 2016). **Note:** Although not explicitly addressed, the Larson et al. (2016) model includes an approach to simulate the effects of sea level rise.

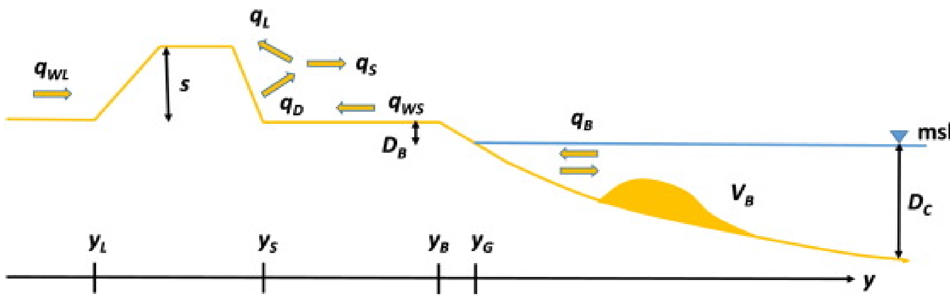

Figure 1: Sketch to calculate cross-shore transport and beach profile evolution (Larson et al., 2016).

Transport equations

- **Dune erosion and overwash**

$$q_D = 4C_s \frac{(R - Z_D)^s}{T} \tag{1}$$

The cross-shore transport rate q_D is related to the runup height R, the distance from the mean water level to the dune foot Z_D, the wave period T and an empirical coefficient C_s.

Where

$$R = 0.158\sqrt{H_0 L_0} \tag{2}$$

The backwash q_s and overwash q_L transports are derived from the cross-shore transport rate q_D:

$$q_s = \frac{q_D}{(1+\alpha)} \tag{3}$$

Parameter	Description	Units
	Sediment transport	
q_{wL}	Constant wind-blown transport on the shoreward side	$m^3s^{-1}m^{-1}$
q_L	Overwash transport	$m^3s^{-1}m^{-1}$
q_D	Cross-shore transport rate	$m^3s^{-1}m^{-1}$
q_s	Seaward transport resulting from erosion of the dune (backwash)	$m^3s^{-1}m^{-1}$
q_{ws}	Constant wind-blown transport towards the dune	$m^3s^{-1}m^{-1}$
q_B	Berm-bar transport	$m^3s^{-1}m^{-1}$
	Morphological locations	
y_L	Location of landward end of the dune/barrier	m
y_s	Location of seaward end of the dune/barrier (dune foot)	m
y_B	Location of berm crest (represents the shoreline position)	m
y_G	Location of still-water shoreline	m
D_C	Depth of closure	m
	Morphological features	
S	Dune height	m
D_B	Berm crest height	m
V_B	Bar volume	m^3m^{-1}

Table 1: List of symbols on Figure 1 .

$$q_L = \frac{\alpha q_D}{(1+\alpha)} \tag{4}$$

where

$$\alpha = \frac{1}{A}\Big(\frac{R - Z_D}{s} - 1\Big) \tag{5}$$

- **Bar-berm material exchange**

$$\frac{dV_B}{dt} = \lambda(V_{BE} - V_B) \tag{6}$$

The change in the bar volume V_B is taken to be proportional to the deviation from its equilibrium value V_{BE}. If V_{BE} and λ are constants, we obtain the solution:

$$V_B = V_{BE} - (V_{BE} - V_{B0})e^{-\lambda t} \tag{7}$$

where V_{B0} is the bar volume at $t = 0$. The bar volume at equilibrium V_{BE} is given by:

$$\frac{V_{BE}}{L_0^2} = C_B\Big(\frac{H_0}{wT}\Big)^{\frac{4}{3}}\frac{H_0}{L_0} \tag{8}$$

where w is the sediment fall speed and C_B a dimensionless coefficient. The parameter λ is the rate coefficient that depends on the wave and sediment properties:

$$\lambda = \lambda_0\Big(\frac{H_0}{wT}\Big)^m \tag{9}$$

where λ_0 and m are coefficients with values to be calibrated against data.

- **Wind-blown sand**

In all the study sites where Larson et al. (2016) model was applied (Palalane et al., 2016), constant values of wind-blown transport towards the dune on the seaward (q_{WS}) and landward (q_{WL}) sides were addopted.

Sediment conservation equations for morphological features

- Bar evolution

$$\frac{dV_B}{dt} = q_B \tag{10}$$

- Berm evolution

$$\frac{dy_B}{dt} = \frac{1}{D_B + D_C}\Big(- q_{ws} - q_B + q_s - \frac{dQ_L}{dx}\Big) \tag{11}$$

where Q_L is the longshore sand transport.

- Dune evolution

$$\frac{dy_s}{dt} = \frac{-q_D + q_{WS}}{s} \tag{12}$$

$$\frac{dy_L}{dt} = \frac{-q_L - q_{WL}}{s} \tag{13}$$

¿where is y_G?

If the beach profile has a fixed shape from the berm crest to the depth of closure, the following relationship holds:

$$y_G = y_B + \frac{D_B}{tan\beta_f} = y_B + L_B \tag{14}$$

where L_B is the horizontal distance from the berm crest to the shoreline (the foreshore length), and $tan\beta_f$ is the foreshore slope.

References

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