Long-term shoreline evolution modeling

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Objectives

Long-term prediction of shoreline evolution remains an important problem for coastal engineering. Our study aims at simplifying longshore transport process and coupling cross-shore and longshore models to find a better parameterization to improve simulation of long-term shoreline evolution.

Application

The model was calibrated with 8-year time-series data of Narrabeen beach, Australia. The shoreline proxy is of -0.7m (mean high tide water level).

Cross-shore transport

- Sediment moves perpendicularly to the shoreline
- Contributes to shoreline variation in short-term
- Main factors: significant wave height H_s, wave period T_p, grain size
- Shoreline position (S) evolution model by cross-shore transport of relaxation type:

$$\frac{\partial S}{\partial t} = G(H_s, T_p) - G_{eq}(S)$$ (Wright & Short,1984; Kriebel & Dean,1993)

- Equilibrium state: $G(H_s, T_p) = G_{eq}(S)$
- Used model: **(ShoreFor model)** $$\frac{\partial S}{\partial t} = c(F^+ + rF^-) + d \quad (1)$$ (Splinter *et al*, 2014; Castelle *et al*, 2014)

F: forcing term, $F = P^{0.5}\frac{\Delta\Omega}{\sigma_{\Delta\Omega}}$, F^+: accretionary forcing term; F^- : erosional forcing term

P: wave energy flux

$\Delta\Omega = \Omega_{eq} - \Omega$; Ω: dimensionless fall velocity, $\Omega = \frac{H_s}{wT_p}$, *w:* settling velocity

Ω_{eq}: equilibrium dimensionless fall velocity, $\Omega_{eq} = \left[\sum_{i=1}^{2\phi} 10^{-i/\phi}\right]^{-1}\left[\sum_{i=1}^{2\phi} \Omega_i 10^{-i/\phi}\right]$

r: erosion ratio, $r = \left|\frac{\sum_{i=0}^{N} F_i^+}{\sum_{i=0}^{N} F_i^-}\right|$; *c, d*: optimized free parameter

d: linear shoreline trend component

Longshore transport

- Sediment moves parallel to the shoreline
- Contributes to shoreline variation in long-term
- Main factors: oblique breaking wave direction, beach angle
- Shoreline evolution model by longshore transport:

$$\frac{\partial S}{\partial t} = -\frac{1}{h_c}\frac{\partial Q}{\partial x}$$ (Pelnard-Considère, 1956)

$$Q = K_1 H_{s,b}^{5/2} \sin 2(\alpha_b(t) - \beta(x))$$

- Equilibrium state: average breaking wave angle perpendicular to the shore. Departure from that wave angle produces longshore drift.
- Suggested model: $$\frac{\partial S}{\partial t} = H_{s,b}^{3/2}\left[a\cos 2\alpha_b' + b\sin 2\alpha_b'\right] \quad (2)$$

Q: volumetric longshore transport rate

h_c: closure depth

$H_{s,b}$: breaking significant wave height

α_b : breaking wave angle

α'_b : fluctuation of breaking wave angle, $\alpha'_b = \alpha_b - \bar{\alpha}'_b$

β: beach angle

a, b: optimized free parameters

Combined model

Replace *d* in (1) with (2) $\Rightarrow$ $$\frac{\partial S}{\partial t} = c(F^+ + rF^-) + H_{s,b}^{5/2}\left[a\cos 2\alpha_b' + b\sin 2\alpha_b'\right] \quad (3)$$

- Free parameters: *a, b & c*
- Method for a, b & c: optimization by Simulated Annealing Algorithm (R package)

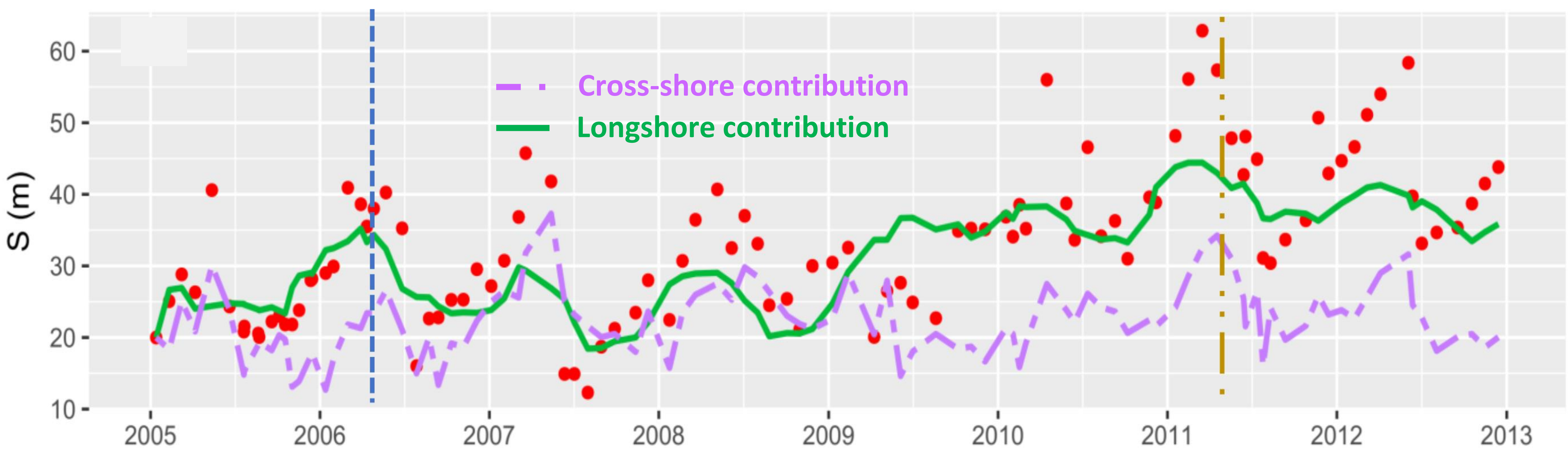

FIGURE 1. Cross-shore contribution and Longshore contribution in Combined model (3)

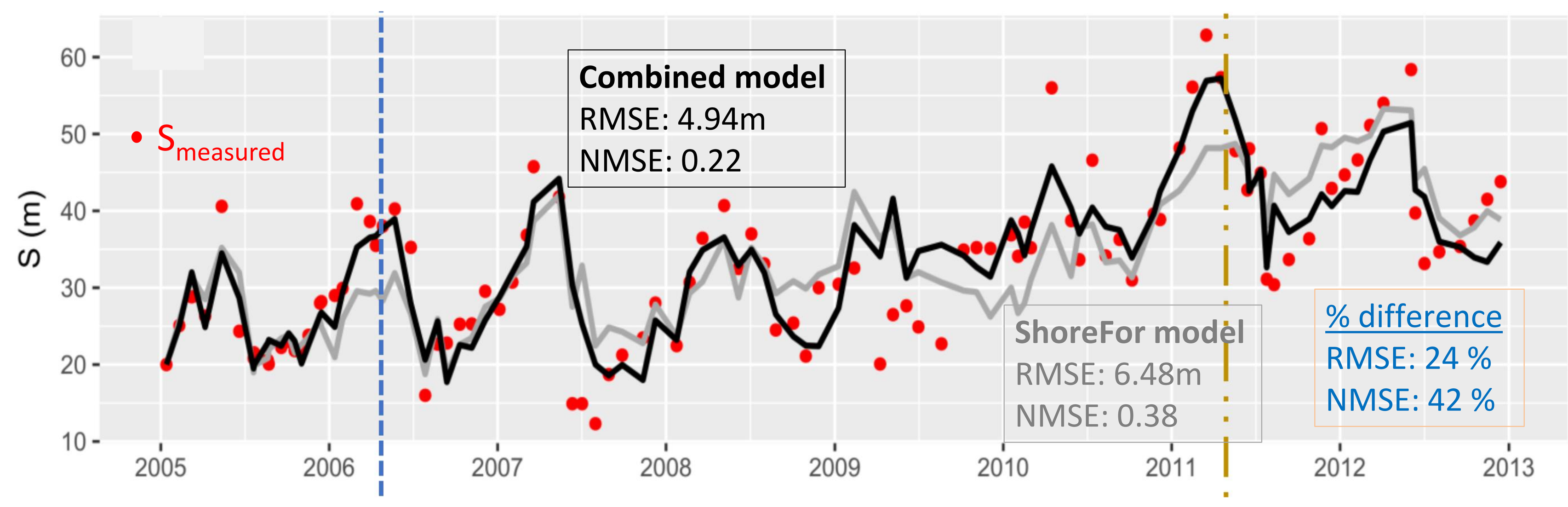

FIGURE 2. ShoreFor model (1) and Combined model (3)

Conclusions and Perspectives

- The development of a numerical model for the shoreline evolution is taking account the longshore transport contribution.
- Our combined model (3) gives an overall improvement over a "pure" cross-shore model (1) .
- In embayed beaches, the combined model (3) is able to provide not only the long-term trend but also the seasonal fluctuations induced by the longshore contribution.
- The combined model (3) reduces the complexity and cost of computation for long-term shoreline simulations.
- The combined model and the cross-shore model still underestimate the variability of the accretion and erosion events → Ω_{eq} need to be revaluated.
- A better understanding of Ω_{eq}, the beach memory and memory decay ϕ should be given special importance.

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