Morphological evolution of ebb-tide deltas

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Introduction

Ebb-tidal deltas (ETD) are sandy morphological structures and form at the interface between a tidal constriction and the open sea where ebb tidal currents and wave action meet. ETDs serve an active role controlling coastal morphology by dissipating and redirecting wave energy, storing sediment for beach nourishment, and are a conduit of sediment bypassing. Deltas serve many critical functions but the processes governing their development and evolution are poorly understood [Fagherazzi and Overeem, 2007]. ETD morphology is highly dynamic, with sandbars shifting in response to changing conditions. There is little known about the short-term episodic movements due to storms and variation in tidal conditions.

Aim

To develop a semi-analytical model in order to gain insight about storm-scale variations of ETD morphology. Identify what parameters govern the movement of sandbar shoreward and seaward. Determine what conditions control the dominance of waves over the ebb-jet in controlling sandbar movement.

Methods

A semi-analytical model is developed to describe tidal jet flow into a directly-opposing wave field. We build upon the approach of Özsoy [1977] to include wave influence on the mean-flow velocity of an ebbing tidal jet. Momentum balance and mass conservation equations for vertically- and laterally-averaged shallow-water jet equations describe the axial velocity, u and jet-width, h with distance from the inlet, x.

2D Jet Equations: (see diagrams for symbol definitions)

\[ I_1 \frac{\partial (hu)}{\partial t} + I_2 \frac{\partial (hu^2)}{\partial x} = -I_2 b C_f \text{sign}(u) |u| + \frac{I_2 b C_f |u| + b}{\rho} F_w \]

\[ \frac{\partial (bu)}{\partial t} + \frac{\partial (hu^2)}{\partial x} = -a h u |u| = 0 \]

In the model, waves attenuate the depth-averaged flow by contributing:

• Excess momentum flux (through radiation stress) as waves shoal and break
• Increased turbulence (transferred into water during wave energy dissipation)
• Increased bed shear stress (from orbital velocities in the bottom boundary layer)

The flow is used as input to sediment flux, Q calculations. The Soulsby [1997] formulae is modified to include Stokes drift in the bed transport. Convergences and divergences in sediment flux are used to update the depth profile, which effectively is the morphological evolution along the jet axis.

Results

Hydraulic calculations with the model compare well with published laboratory observations and numerical Delft3D model simulations, both with a steady jet flowing into a directly opposing, non-breaking wave field with flat bottom, \( h = 0.114m \) and \( h = 3m \), respectively [Ismail and Wiegel, 1983; Nardin et al., 2013].

As expected, with waves the jet width increases and axial velocity decreases relative to the no-wave case. Further, the existence of a convergence point occurs in cases where momentum from waves overwhelms the jet.

Key Findings

• Existing analytic jet model improved by including waves and turbulence
• Simple model able to generate/degenerate, move, and predict growth rate of sandbars
• Sediment response rate increases with waves opposing ebb-jet (convergence)

References


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