A first look at the dynamic interaction between waves and flow discharge through twin-deltaic channels with a coupled model

Matthew Afola1, Stephen Darby1, Eli Lazarus1
1School of Geography and Environmental Sciences, University of Southampton, SO17 1BJ, UK.
Correspondence: mra1u19@soton.ac.uk

1. Research Background

- Longshore currents generated by waves transport sediment along the coastline.
- Gradients in longshore sediment transport (LST) due to wave climate or shoreline orientation.
- Gradients also from obstruction of the LST by the river jet (the "groyne effect") [1].
- How does this coupling between flow discharge and LST occur at multiple deltaic river mouths?
- Numerical model to investigate the plan-view deltaic evolution due to the dynamic interplay between flow discharge and waves is presented.

2. Methods

2.1 Overview of the Delft3D model

- Modelling involves Delft3D Flow and SWAN.
- Flow domain: 7.5 km (alongshore) by 5 km (offshore).
- 252 by 115 grid cells in M x N directions.
- Wave domain: 30 km (alongshore) by 5 km (offshore).
- 202 by 64 grid cells in M x N directions.
- Large >> 186 km by 90 km.
- Small >> 181 grid cells in M x N directions.
- Small wave domain is nested in the large domain.

2.2 Numerical modelling scenarios

- Water discharge increasing from 200m^3/s^1 to 1000m^3/s^1.
- Sediment concentration at Q01 = 0.1*(Q01 + Q05).

2.3 Model set up

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation</td>
<td>31 days</td>
</tr>
<tr>
<td>Spins-off</td>
<td>1 day</td>
</tr>
<tr>
<td>Rain changes</td>
<td>30 days</td>
</tr>
<tr>
<td>MorFace</td>
<td>75</td>
</tr>
<tr>
<td>Time step</td>
<td>0.5 (1 min)</td>
</tr>
<tr>
<td>Numerical updates</td>
<td>7.5 min (i.e., MorFace*TimeStep)</td>
</tr>
<tr>
<td>Total simulation period</td>
<td>2500 days = 6.5 years</td>
</tr>
<tr>
<td>Number of simulations</td>
<td>29</td>
</tr>
<tr>
<td>'updrift' sediment D50</td>
<td>201 µm</td>
</tr>
<tr>
<td>'midshore' sediment D50</td>
<td>200 µm</td>
</tr>
<tr>
<td>'downdrift' sediment D50</td>
<td>199 µm</td>
</tr>
<tr>
<td>Fluvial sediment D50</td>
<td>202 µm</td>
</tr>
</tbody>
</table>

2.4 Analysis

- The sediment fractions bypassing the river mouths B: β = Qr1/Qr2
- The momentum jet balance, J relates per unit width of fluvial discharge with the corresponding nearshore wave power [2]:
  \[ J = \frac{Qr^2}{2} \]  
- To compute a deltaic shape factor: \( A = \frac{L}{W} \) \( B = \frac{V}{L} \)
- To compute a deltaic shoreline ruggedness:

3. Results

3.1 Dynamic interaction between the jet and LST

- The pathways of the longshore mass flux (LMM) indicated with white arrows and the river planes with red arrows.
- Model simulations with identical fluvial input: Q400m^3/s^1.
- Differences in wave climates informed the degree of LST connectivity.
- Lower Hs (1.0m) >> discontinuous LMM while higher Hs (1.5m) >> continuous LMM.

4. Discussion

- Cross-shore progradation of the modelled delta is subdued at the expense of longshore extension under high intensity wave energy.
- This is because generated LST effectively redistributes fluvial sediment across the coastline as Ht increases [5].
- Deltaic river mouth forms, range from the extreme case of wave dominance characterized by downdrift deflected-downdrift, to the symmetric deltaic shorelines with slight deflection of the river jet which is indicative of negligible LST [4, 5].
- Both shoreline ruggedness and cross-shore - alongshore aspect are a function of the balance of the deltaic river mouth interaction [3].

5. Summary and Future Work

- Wave action along a multi-channel coastline can produce a complexity of deltaic planform morphologies and behaviours.
- The magnitudes and pathways of the wave-driven longshore sediment fluxes depend principally on the wave height, (Ht).
- However, model simulations did not clearly demonstrate the hydraulic groyne effect of the river plume on wave-derived LST.
- Future work will attempt to extend the coupled modelling to critically examine natural delta examples to gain better insights into the dynamic coupling between fluvial and ocean wave processes.

6. References


7. Acknowledgements

- CSDMS (Community Surface Dynamics Modeling System).
- BSG (British Society for Geomorphology).
- PDPD (Philippe Dechamps Development Fund).
- MRA (M. R. A. Darby).