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

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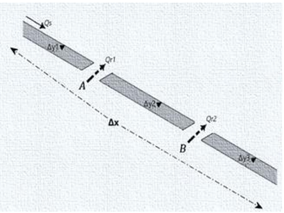
1. Research Background

- 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.

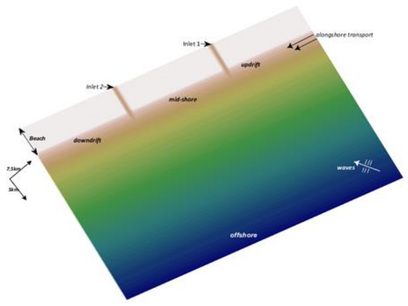


Schematic of the interplay between the fluvial discharge and longshore sediment transport along an idealised deltaic coastline

- Twin deltaic channels >> ***A*** & ***B***
- ***Qr1*** & ***Qr2*** >> flow discharge from ***A*** & ***B, respectively***
- ***Qs*** >> net LST due to oblique wave approach
- ***A*** & ***B*** delimits the coastline into:
- 'updrift' of 'A'
- 'mid-shore' between 'A' & 'B'
- 'downdrift' of 'B'

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 >> comprises:
- Small >> 30 km (alongshore) by 5 km (offshore)
- 202 by 64 gird cells in M x N directions
- Large >> 186 km by 90 km
- 94 by 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 $200m^3s^{-1}$ (Q01) – $1000m^3s^{-1}$ (Q05)
- Sediment concentration at 0.1*(Q01 – Q05) kgm^{-3}

a. LST maximising wave climate: Low (***QL****-01 – 05*) & high (***QH****-01 – 05*) sediment concentration scenarios (Hs: 1.5m; θ: 42°)
b. QHs*-01 – 05*: Reduced wave energy density; wave incidence angle optimised (Hs: 1.0m; θ: 42°)
c. QD*-01 – 05*: Reduced wave incidence angle; model optimum wave energy (Hs: 1.5m; θ: 24°)
d. QW*-01 – 05*: Moderate wave climate (Hs: 1.0m; θ: 12°)
e. QLW*-01 – 05*: Low wave climate (Baseline scenario) (Hs: 0.75m; θ: 06°)

2.3 Model set up

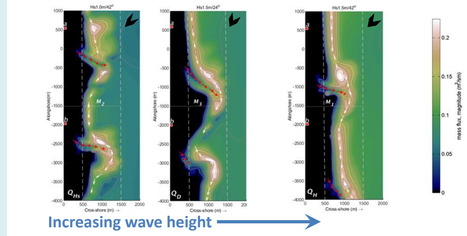
Variable	Value
Simulation	31 days
Spin-off	1 day
Bed changes	30 days
MorFac	75
Time step	6s (0.1 min)
Numerical updates	7.5 mins (i.e., Morfac*Timestep)
Total simulation period	2250 days ~ 6.2 years
Number of simulations	29
'updrift' sediment D_{50}	201 µm
'midshore' sediment D_{50}	200 µm
'downdrift' sediment D_{50}	199 µm
Fluvial sediment D_{50}	202 µm

2.4 Analysis

- The sediment fractions bypassing the river mouths β: $\beta_n = \frac{Vu_n d}{Vu_n}$
- The momentum jet balance, *J* relates per unit width of fluvial discharge with the corresponding nearshore wave power [2]: $J = \frac{\rho * Q * u}{S_{xy} * W} = \frac{\rho * Q * u}{E * n(Cos\theta * Sin\theta) * W}$
- To compute a deltaic shape factor: $A = \frac{B}{2L}$
- To compute a deltaic shoreline rugosity: $R = \frac{Contoured\ distance}{Planar\ distance}$

3. Results

3.1 Dynamic interaction between the jet and LST



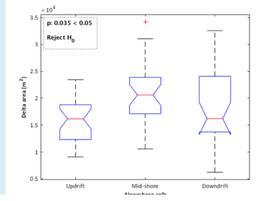
Wave climates

- Left: Hs1.0m/42°
- Middle: Hs1.5m/24°
- Right : Hs1.5m/42°

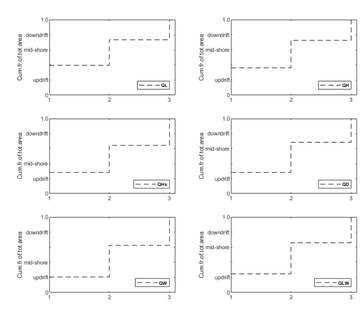
The pathways of the longshore mass flux (LMF) indicated with white arrows and the river plumes with red arrows

- Model simulations with identical fluvial input : $Q400m^3s^{-1}$/$Qr40kgs^{-1}$
- Differences in wave climates informed the degree of *LMF* connectivity
- Lower Hs (1.0m) >> discontinuous *LMF* **while** higher Hs (1.5m) >> continuous *LMF*

3.2 Subaerial delta extent



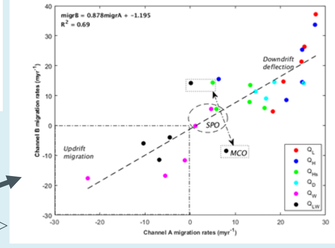
- The box and whisker plot with ANOVA (***inset***) indicates that the areal extent of the sub-deltaic islands have a statistically significant variation.

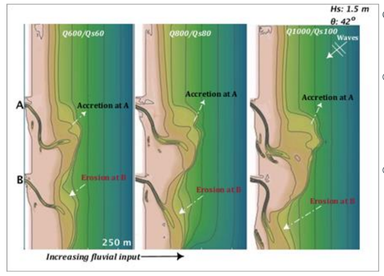


- Plots of the cumulative fractions of the sub-deltaic islands in the total delta area.
- Distribution of the areal extents of the sub-delta islands more skewed under low wave intensity.
- Higher wave power >> ensures even distribution of fluvial sediment shore wide [3].

3.3 Deltaic river mouth morphology

- Higher wave power >> both channels deflected downdrift
- Updrift channel migration >> low/moderate wave power
- Mixed channel orientation (MCO) and shore-perpendicular orientation (SPO) of the channels >> moderate wave power

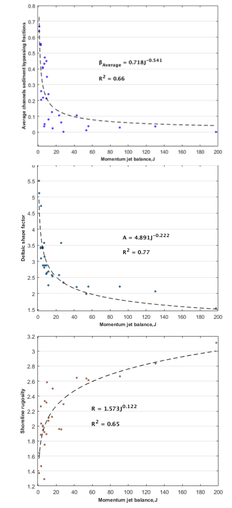




- ***Selected model deltas showing the pattern of deltaic river mouth morphology***
- As ***A*** reorient as orthogonal to the shore direction, subaqueous sand accretion progrades at the river mouth relative to the fluvial sediment influx.
- At ***B*** erosion intensifies relative to the degree of progradation at ***A***

3.4 Predicting morphodynamic relationships

The balance of the delta river interaction, J is employed as an index of the relative influences of flow discharge and waves in the coupled morphodynamic interactions.



- The fractions of alongshore sediment bypassing the deltaic channels ***β***, and the balance of the river mouth interaction ***J***.
- The inverse power law relationship (R^2: 0.66) suggests that alongshore sediment bypassing the channels is higher at lower fluvial power
- The deltaic shape factor ***A***, and the balance of the river mouth interaction, ***J***.
- The inverse power law relationship (R^2: 0.77) suggests that the modelled deltas' cross-shore extent increases with fluvial power.
- The deltaic shoreline rugosity ***R***, and the balance of the river mouth interaction, ***J***.
- The direct power law relationship (R^2: 0.65) indicates that the deltaic shorelines increase in roughness under higher fluvial power.

4. Discussion

- Cross-shore progradation of the modelled deltas is subdued at the expense of alongshore extension under high intensity wave energy.
- This is because wave-generated LST effectively redistributes input fluvial sediment across the coastline as *Hs* increases [3].
- Deltaic river mouths forms, range from the extreme case of wave dominance characterised by downdrift defected shoreline, to the symmetric deltaic shorelines with slight/no deflection of the river jets which is indicative of negligible LST [4], [5].
- Both shoreline roughness 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, (Hs).
- 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

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7. Acknowledgements

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