Wave, Tide and Morphological Controls on Embayment Circulation and Headland Sand Bypassing

EGU General Assembly 2020

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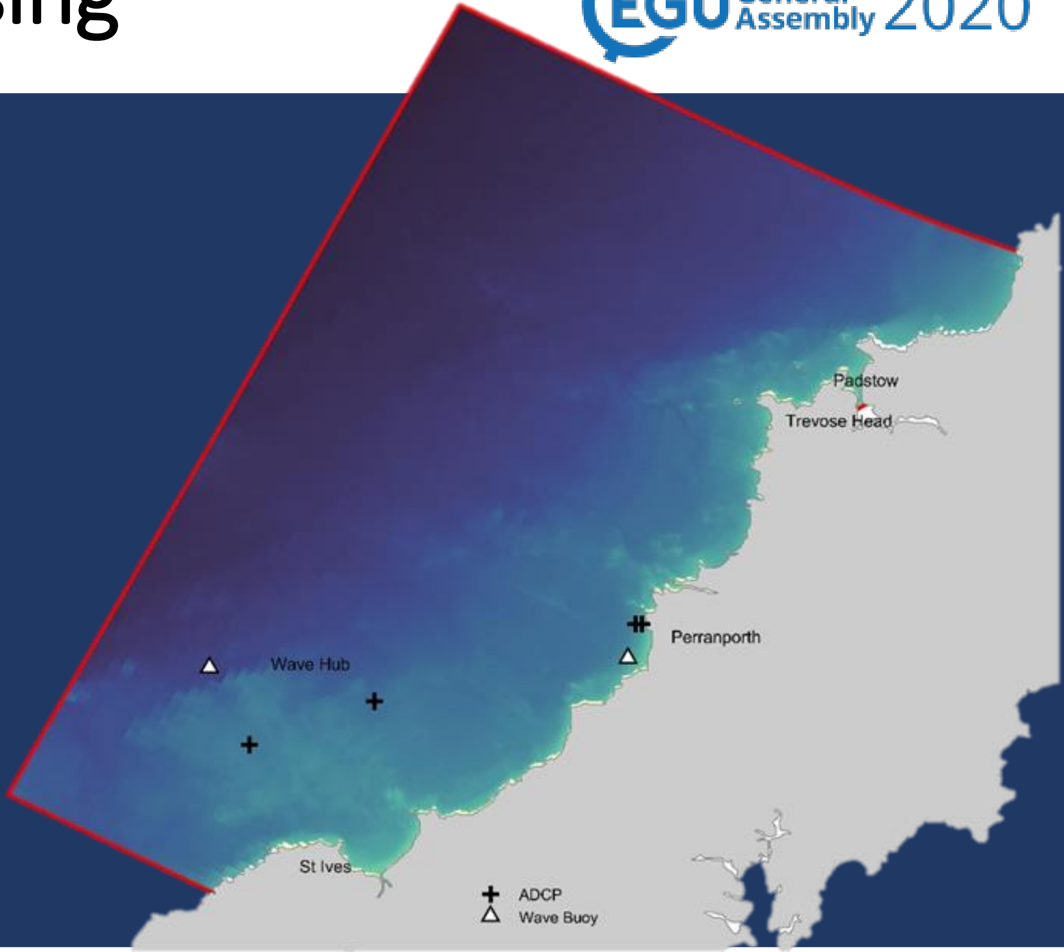

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Introduction

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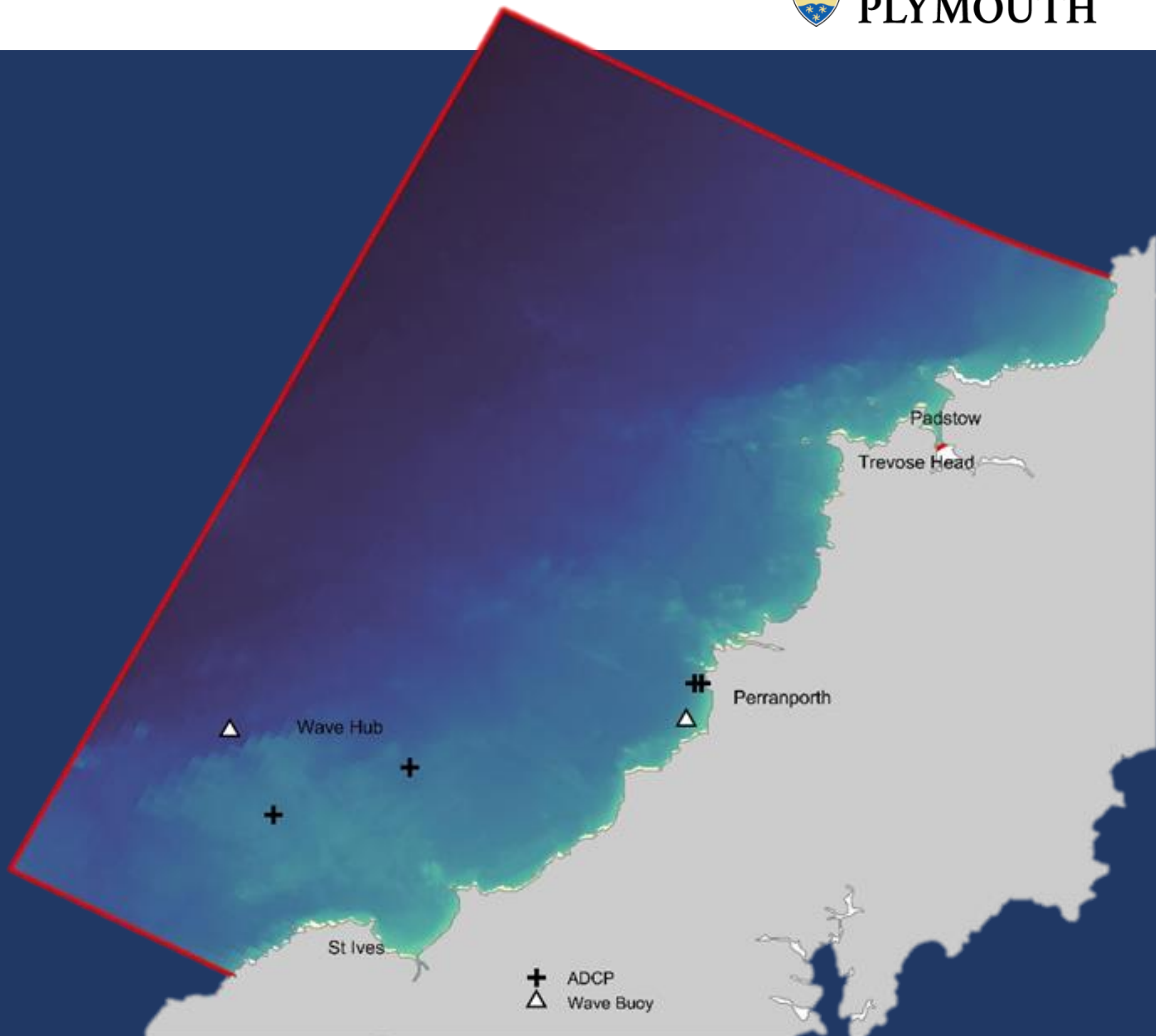
- Embayed beaches make up ~ 50% of global shorelines.
- Important to know sediment sources and sinks into bays to understand sediment budget and coastal evolution.
- Sand can move around headlands under wave and tidal forcing – called headland bypassing.
- Bypassing can be predicted for idealised headlands[1] – remains to test parameterisations under realistic conditions.
- South West UK used as test site with 29 headlands across 75 km of embayed coast.



[1]McCarroll et al., (Under Review). A general expression for wave-induced sediment bypassing of an isolated headland. *Coastal Engineering.*

Methods

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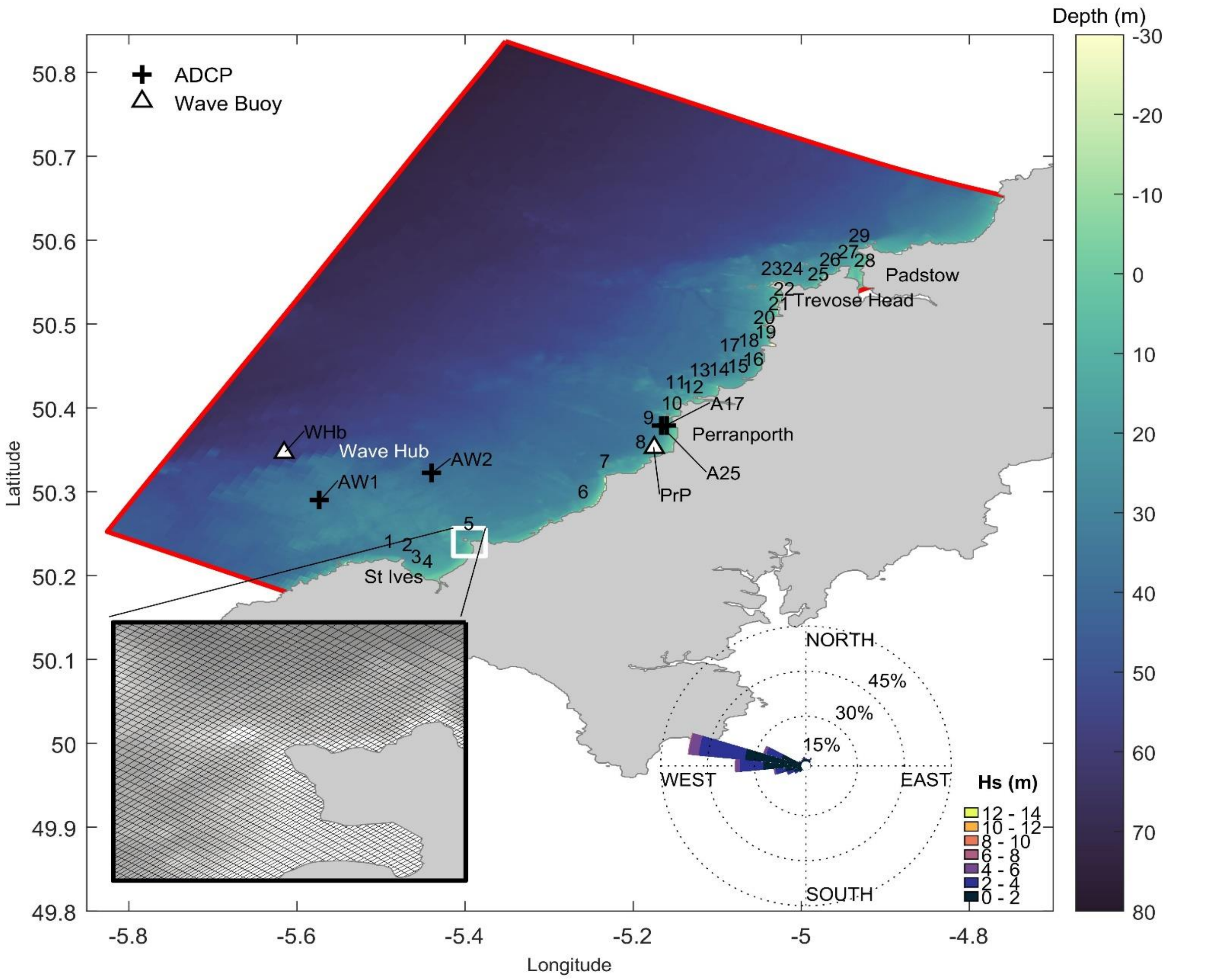
- 3D coupled hydrodynamic and wave model (Delft3D). 50 m resolution on headlands. Sand transport using TRANSPOR2004[1] formulation.

- Validated at ADCP offshore of headland at Perranporth, and wave buoys across domain.

- Scenarios tested for waves-only at different water levels with uniform and spatially variable sediments inferred from high-resolution bathymetry.

- 9 wave scenarios at spring high and low water – Median, Large (5% exceedance) and Extreme (12h exceedance) from 3 directions.



[1]van Rijn, L. C. (2007a). Unified view of sediment transport by currents and waves. I: Initiation of motion, bed roughness, and bed-load transport. Journal of Hydraulic Engineering., 133(6), 649– 667.

Morphology/ Parameters

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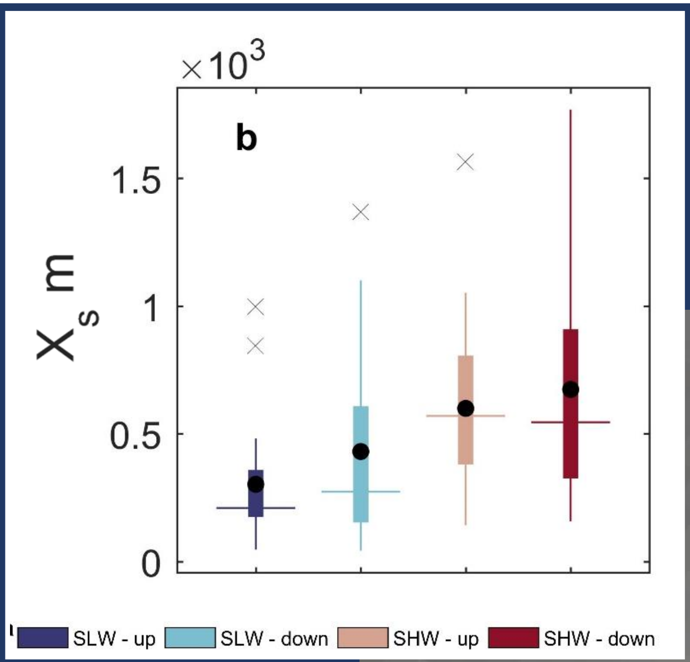
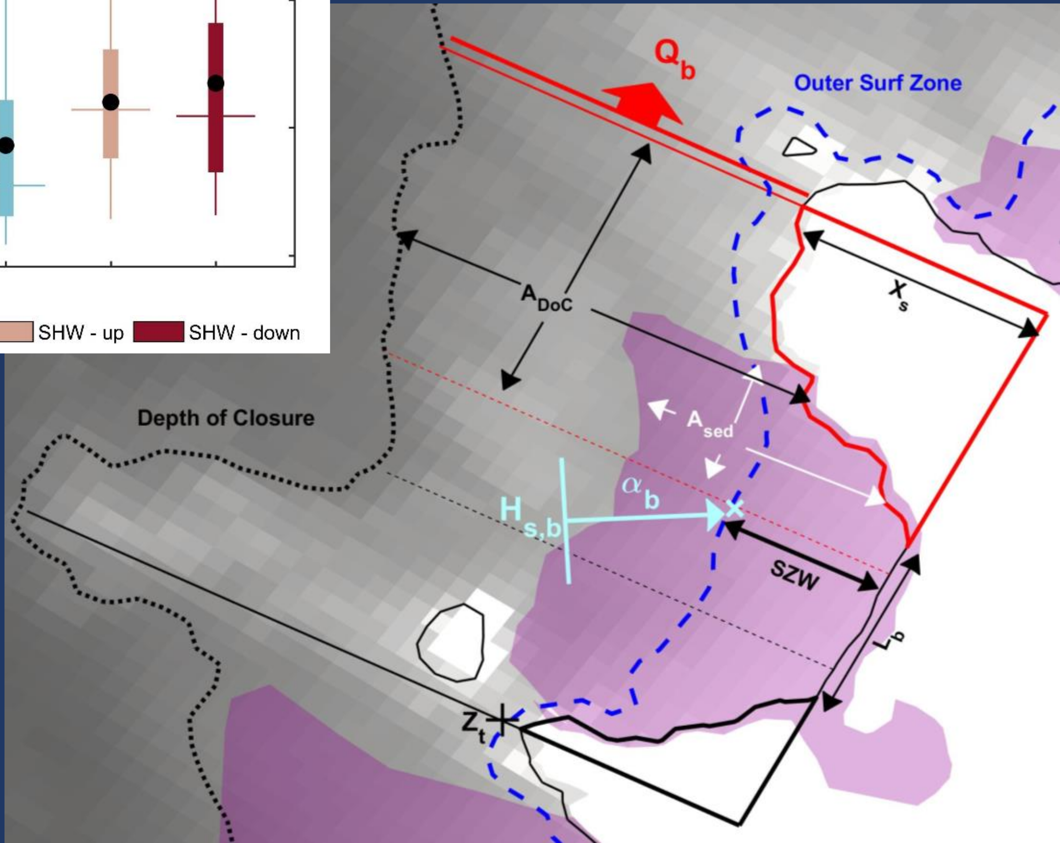
- Headlands split into upcoast and downcoast apparent morphology.
- Apparent morphology changes with water level (SHW Vs SLW)
- Parameters quantified include:
  - X_s – Cross-shore length
  - SZW – Surf zone width
  - L_b – Beach length
  - Z_t – Toe depth
  - $R_{sed} = A_{sed} / A_{DoC}$ – Sand coverage ratio
  - $H_{s,b}$ – Breaking wave height
  - α_b – Breaking wave angle
- X_s tended to be smaller upcoast Vs downcoast – may predispose towards upcoast bypassing.





Sand bypassing Q_b

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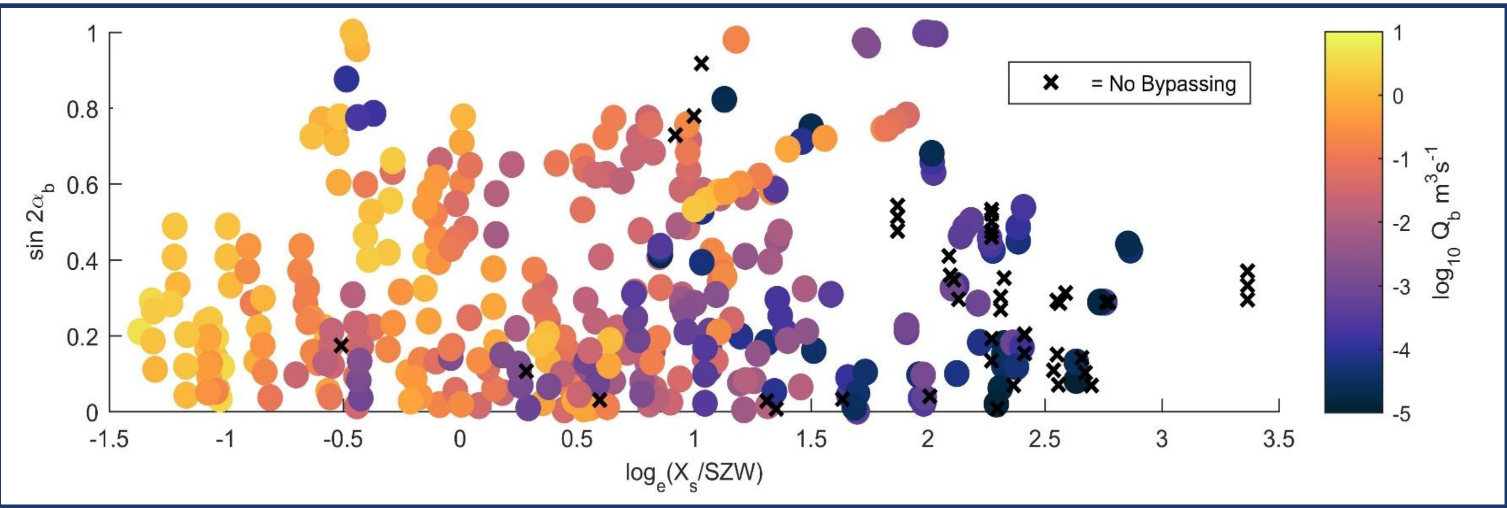
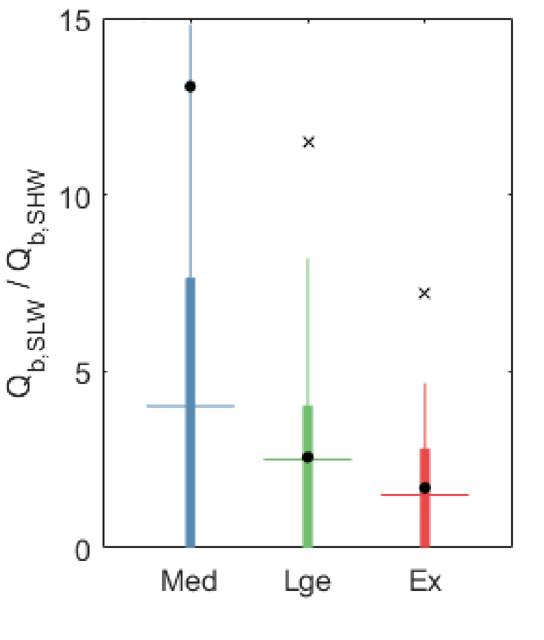
- Q_b strongly dependent on X_s / *SZW*
  - as per McCarroll et al., (Under Review)
- Very little bypassing for $X_s > 5 \times SZW$
- Q_b at SLW ~ 2 × Q_b at SHW with greater effect at smaller wave heights. This can be accounted for with changes to apparent morphology.
- Parameter of McCarroll et al., (Under Review) has RMSE of factor 4.6 and MAE of factor 2.7 against Delft3D model after minor adjustment.

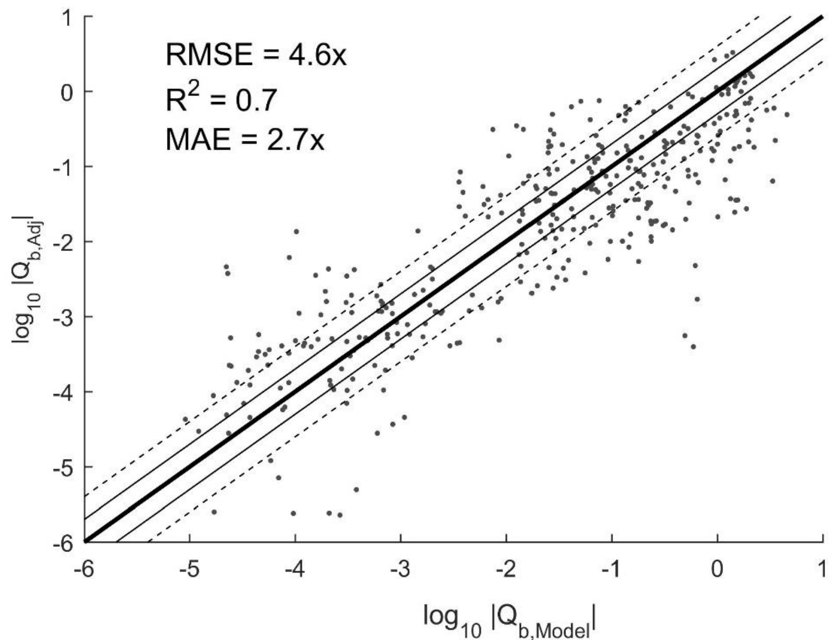
$$Q_{b,Adj} = Q_0 \cdot e^{\left(\frac{X_S}{SZW}\right)^{0.5}}$$

Q_0 – Uninhibited longshore transport using van Rijn (2014)

van Rijn, L. C. (2014). A simple general expression for longshore transport of sand, gravel and shingle. *Coastal Engineering*, 90, 23–39.







New bypassing parameter

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- Depth off headland toe accounted for using:

$$m_t = \frac{Z_t}{50\ m}$$

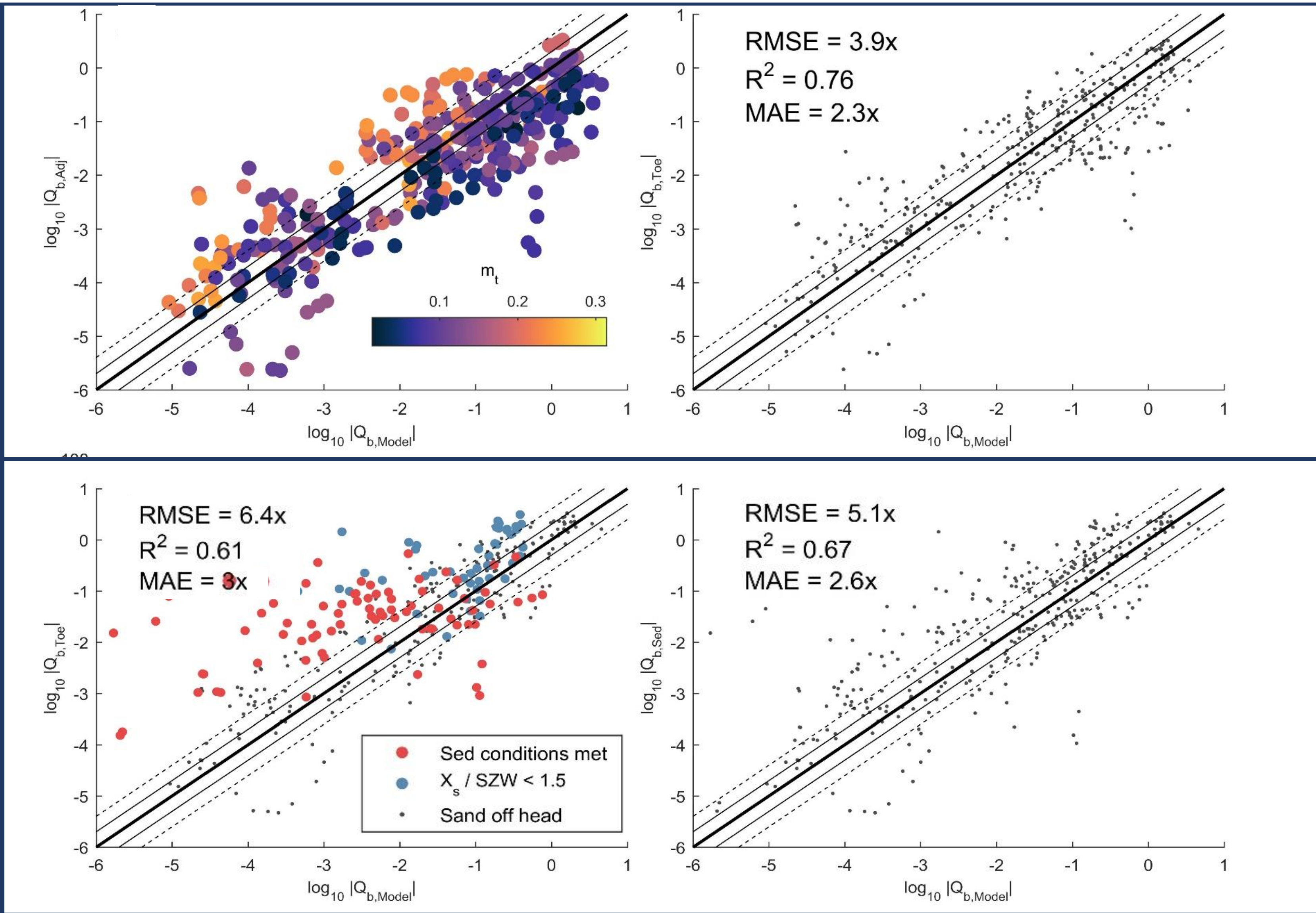
- Brings RMSE < factor 4 for uniform sediments when applied as term in exponential.

- Sediment coverage accounted for using:

$$S_p = \frac{X_s}{Z_t \cdot R_{sed}}$$

- Applies when no sand off headland and $X_s > 1.5 \times SZW$.

- Brings RMSE to factor 5.1 from factor 6.4 over all headlands, and MAE < factor 3, when applied as a term within the exponential. Bigger relative improvement if only data where the above conditions apply are considered.



Conclusions

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- Headland bypassing is amenable to parameterisation.

- Current parameterisations based on idealised isolated headlands can be improved by accounting for toe depth and sediment spatial availability when considering realistic coastal morphologies.

- Waves are the primary forcing mechanism for headland bypassing.

- Tidal water level variations are a secondary forcing mechanism, by changing apparent headland morphology.

- Key morphological parameters are cross-shore headland extent, toe depth and sediment coverage adjacent to the headland.

Next steps

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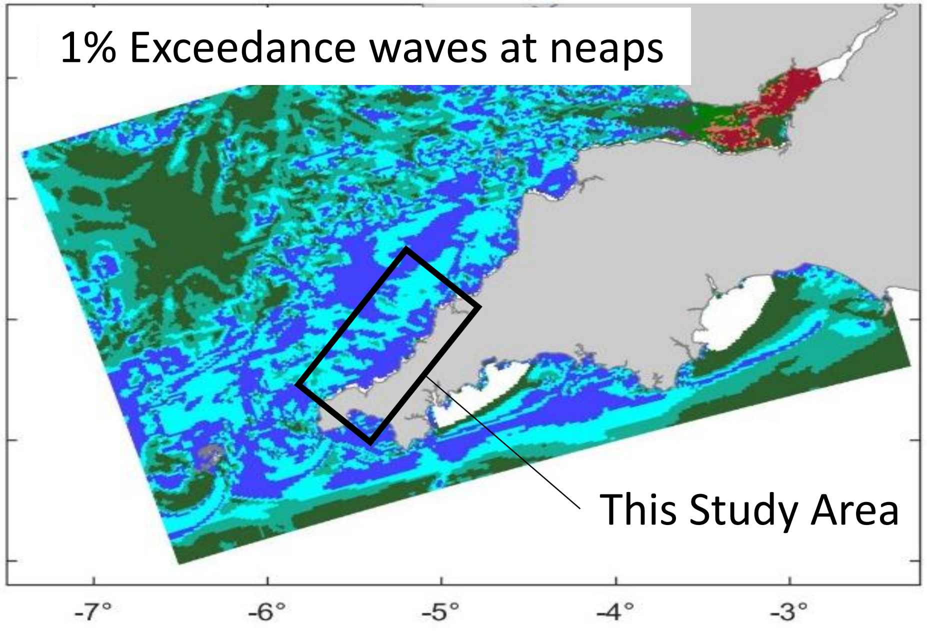
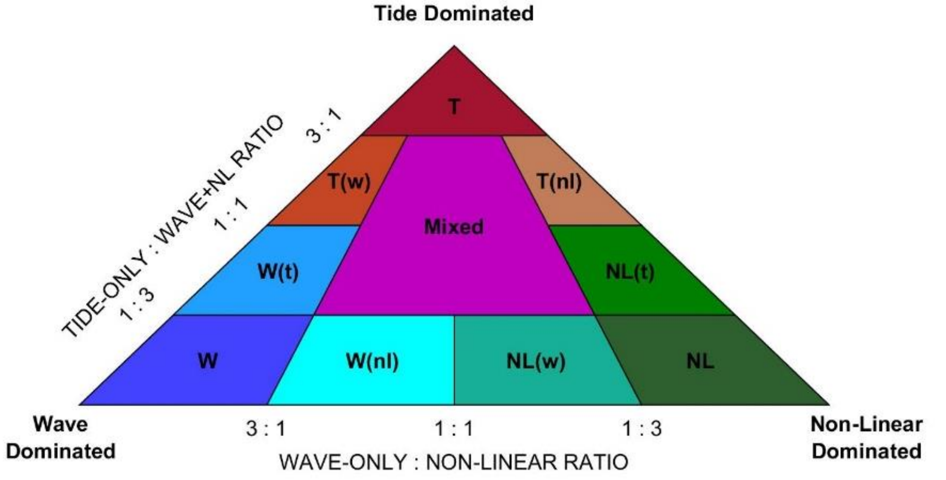
The effect of tidal currents

- North Coast sand transport is generally wave-dominated (King et al., 2019).
- We expect tidal currents to be a secondary factor relative to waves during large or extreme events.
- Wave-tide interactions can have a significant impact on sand transport rates along this coast even at neaps (King et al., 2019), the impact of these interactions on headland bypassing will be quantified.
- Wave-tide and tide-only scenarios for all conditions have been completed and are under processing.





King, E. V., Conley, D. C., Masselink, G., Leonardi, N., McCarroll, R. J., & Scott, T. (2019). The impact of waves and tides on residual sand transport on a sediment-poor, energetic, and macrotidal continental shelf. *Journal of Geophysical Research: Oceans*, 124, 4974– 5002.

Thank you!

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Thanks for reading!

I am happy to talk further via email:
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