INVESTIGATING THE RESILIENCE OF SALT MARSHES TO EXTERNAL DISTURBANCE

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Paper 1
‘Saltmarsh resilience to sea-level rise and increased storm intensity’ **+ follow-up work**

Paper 2
‘Influence of sediment availability and embankment construction on salt marsh resilience to sea-level rise’

- Salt marshes act as natural, long-term, low-cost coastal defences by buffering storm waves and stabilising sediments.

- Marshes are found in intertidal areas and their growth happens by vertical and lateral accretion, which occurs by delivery of fine sediments from rivers and the sea to accommodation spaces.

- Marsh resilience can be monitored analysing the **sediment budget =** balance between sediment added to and removed from the marsh, when more material is added than it is removed, there is a surplus of sediment and the shore builds seaward, and vice versa.

Paper 1 - ‘Saltmarsh resilience to sea-level rise and increased storm intensity’

Aim and objectives

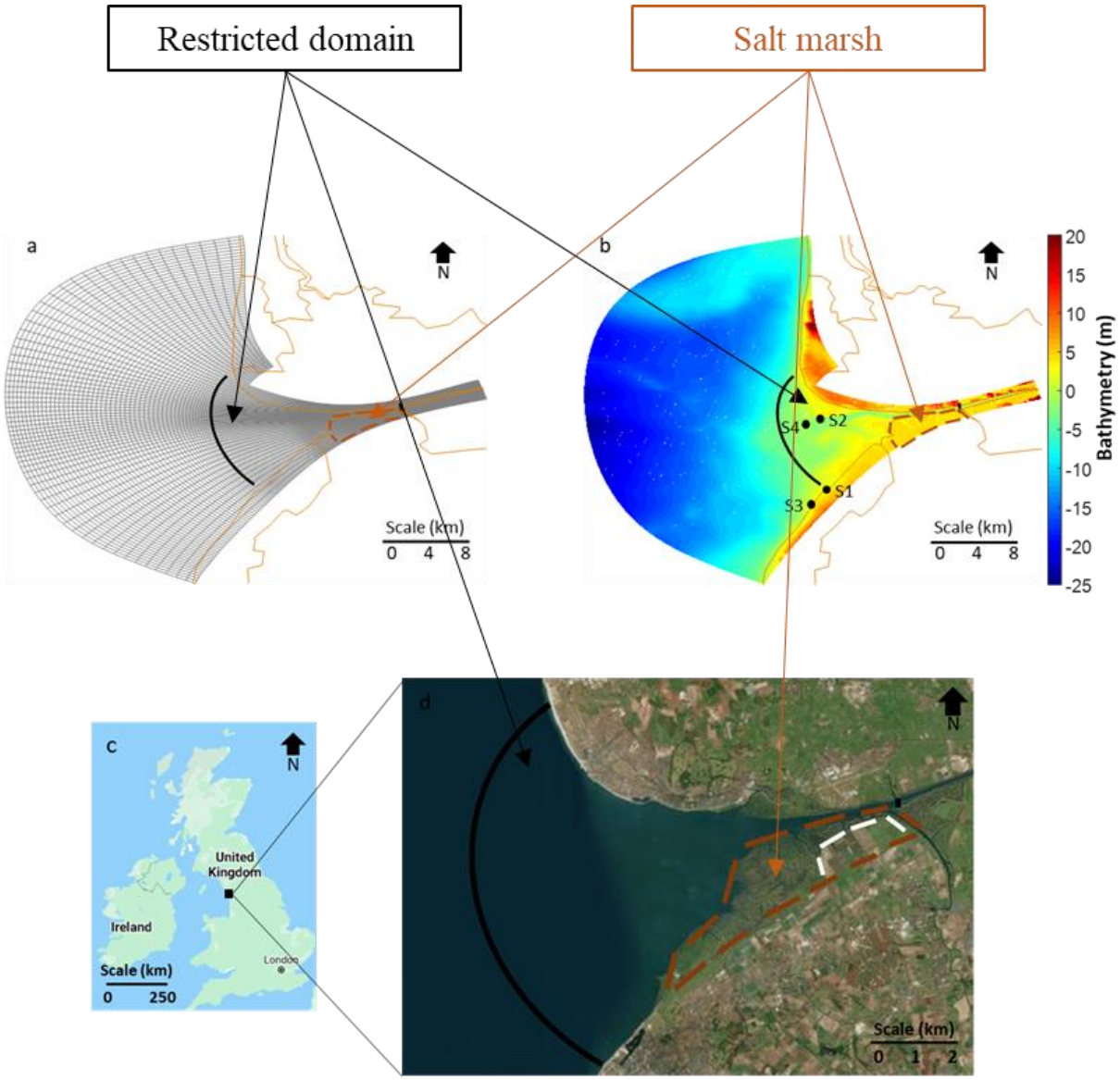
To investigate marsh and estuary resilience under various storm surge and sea-level scenarios by using a sediment budget approach and the hydrodynamic model Delft3D:

- Change in sea-level only
- Change in surge intensity only
  - timing of the storm surge relative to high or low tide
  - duration of the surge
  - change in tidal range
- Combination of storm surge and sea-level scenarios

One month of simulation.

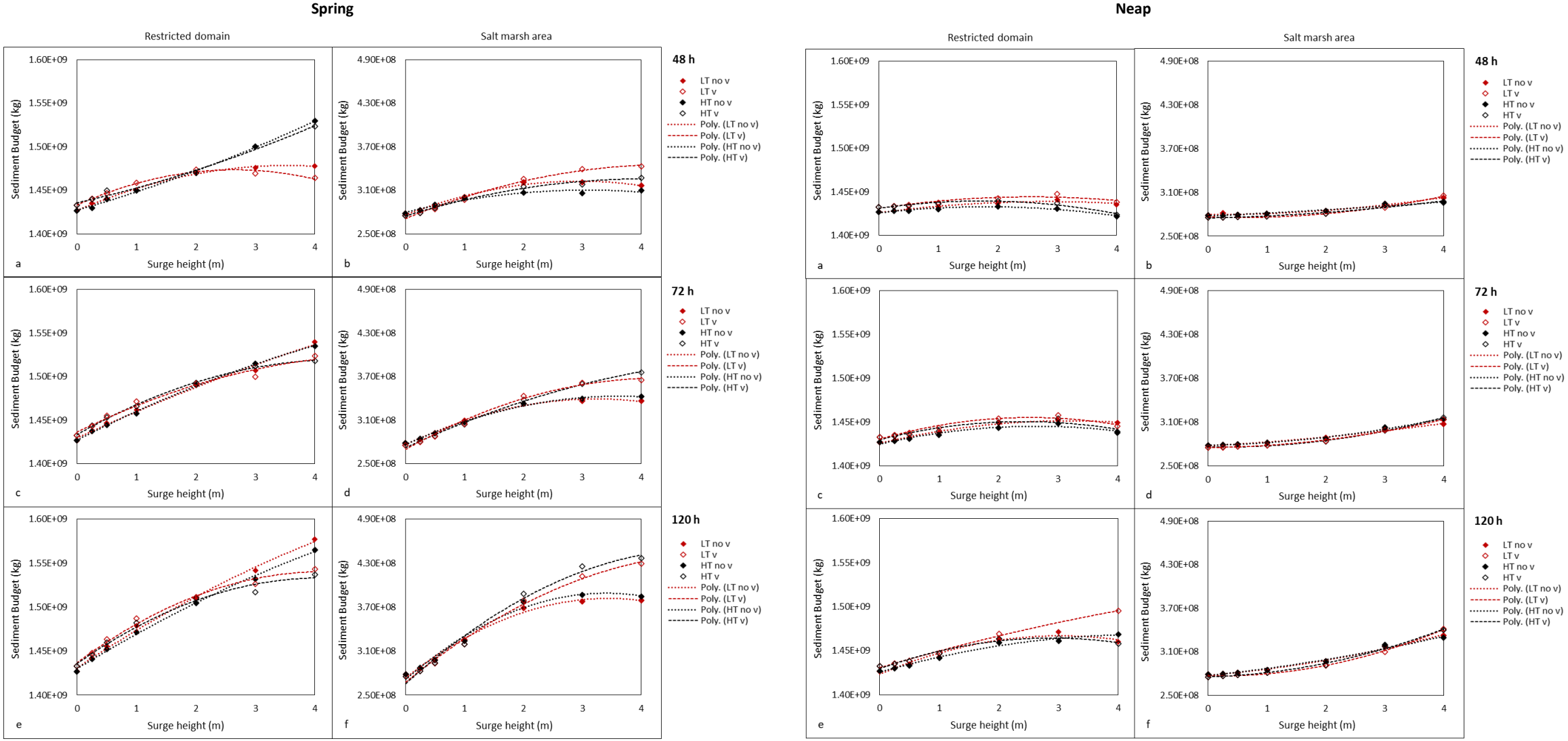
Case study - Ribble Estuary (North West England):

- Funnel shaped, hypertidal.
- One of the largest tidal flat - salt marsh complexes in Europe, part of which has been recently restored through managed realignment.

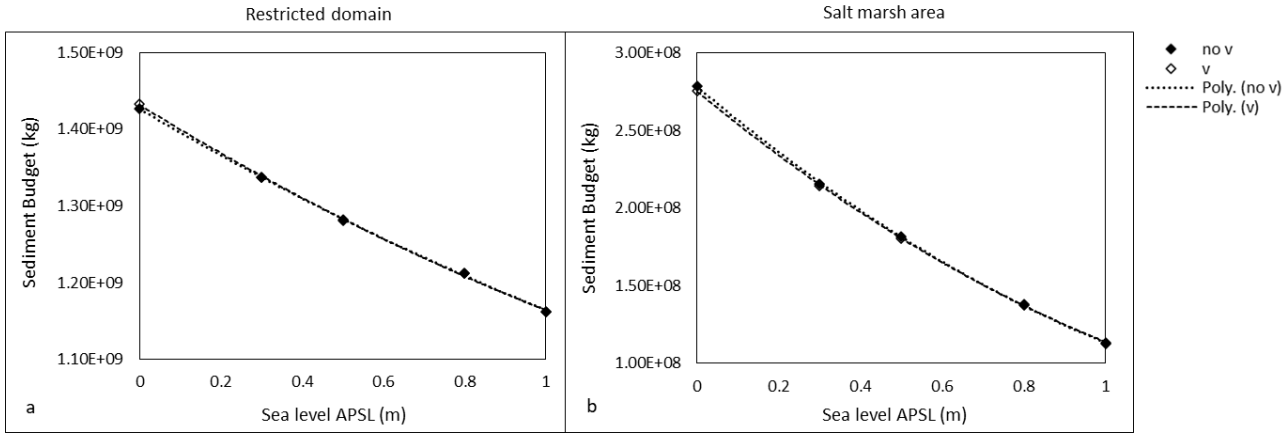


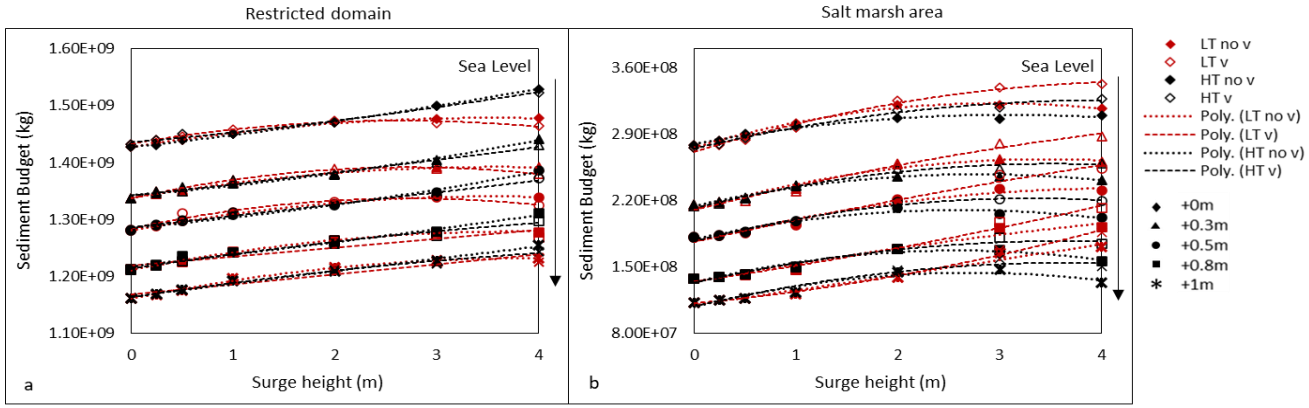
Results: sediment budget

- Deposit increases when the surge height increases.
- Timing of the surge with respect to HT and LT and presence of vegetation can affect the trends.
- With longer storm duration or lower tidal range these effects decrease and become negligible.



Results: sediment budget





Sea-level

- Deposition decreases with an increase in sea-level.

Sea-level + storm surges (48h spring)

- The trends in deposition caused by the increase in surge height remain similar in all sea-level scenarios.
- There is an overall decrease in the magnitude of deposition with the increase in sea-level.
- The effects of storm surges mask the effects of sea-level rise on the sediment budget; this is especially true for surges with the highest intensities (>3 m).

Key points

- Storm surges could contribute to salt marsh and estuarine resilience
- Sea-level rise will threaten the stability of the marsh
- Storm surges might contribute to increase salt marsh resilience to sea-level rise

References

Pannozzo N., Leonardi N., Carnacina I., Smedley R. (2021). Salt marsh resilience to sea-level rise and increased storm intensity. *Geomorphology*, 389 (4): 107825.

Pannozzo N., Leonardi N., Carnacina I., Smedley R. (2021). Dataset of results from numerical simulations of increased storm intensity in an estuarine salt marsh system. *Data in Brief*, 38 (6): 107336.

Follow-up work

‘Investigating spatial distribution of storm deposit on the marsh platform and its transport pathway’

- Investigate parameters that affect spatial variability of storm sedimentation on the marsh platform
- Investigate provenance of sediment that are transported on the marsh platform by storms

1. Analysis performed on simulated surge scenarios (the ones just discussed)

   + machine learning tools used to

   - classify significance of the various hydrodynamic and morphological parameters impact on the different tidal flat/salt marsh areas + generate predictor for calculating sediment budget for the different areas given certain hydrodynamic conditions

   - investigate sediment connectivity to understand the provenance and pathways of storm sediment from ocean to marsh

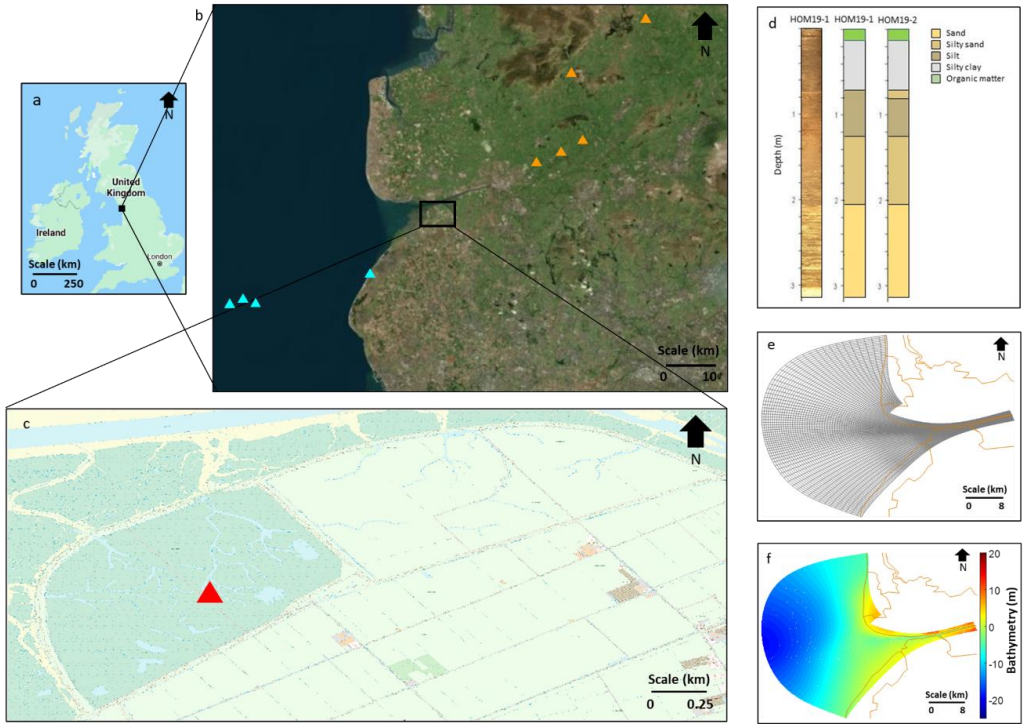
2. Analysis performed on sediment collected in the field using sediment traps

   - sediments collected from the marsh platform on a monthly basis as well as sediments collected from possible sources

Paper 2 - ‘Influence of sediment availability and embankment construction on salt marsh resilience to sea-level rise’

Case study - Ribble Estuary (North West England):

- Widespread anthropogenic interventions including embankment construction since 1810.
- Marsh accreting at a fast rate, previously thought to be linked to embankment presence.



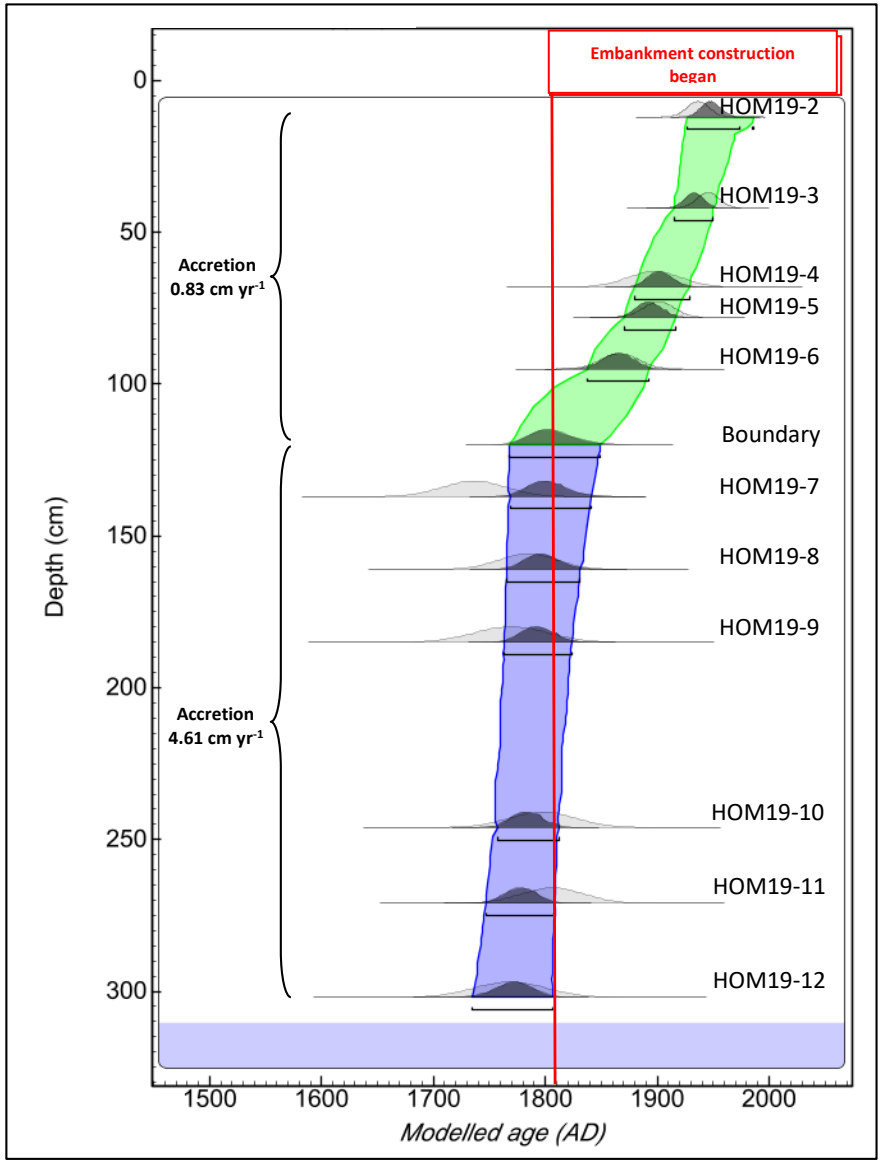
Aim and objectives

Investigate salt marsh resilience to sea-level rise in relation to sediment supply and embankment construction using a combination of paleoenvironmental analysis and Delft 3D:

- Investigate provenance of sediments performing geochemical analysis on sediments from the marsh and possible sources (i.e. river, ocean);
- Detect changes in sediment accretion rate using OSL alongside down-core changes in particle size distribution, geochemistry and organic content to detect changes or shifts in sedimentation processes and depositional environment;
- Compare changes to a record of estuary management to investigate any correlation with embankment construction;
- Use Delft3D to investigate sediment budget calculated from numerical simulations modelling scenarios with and without embankment.

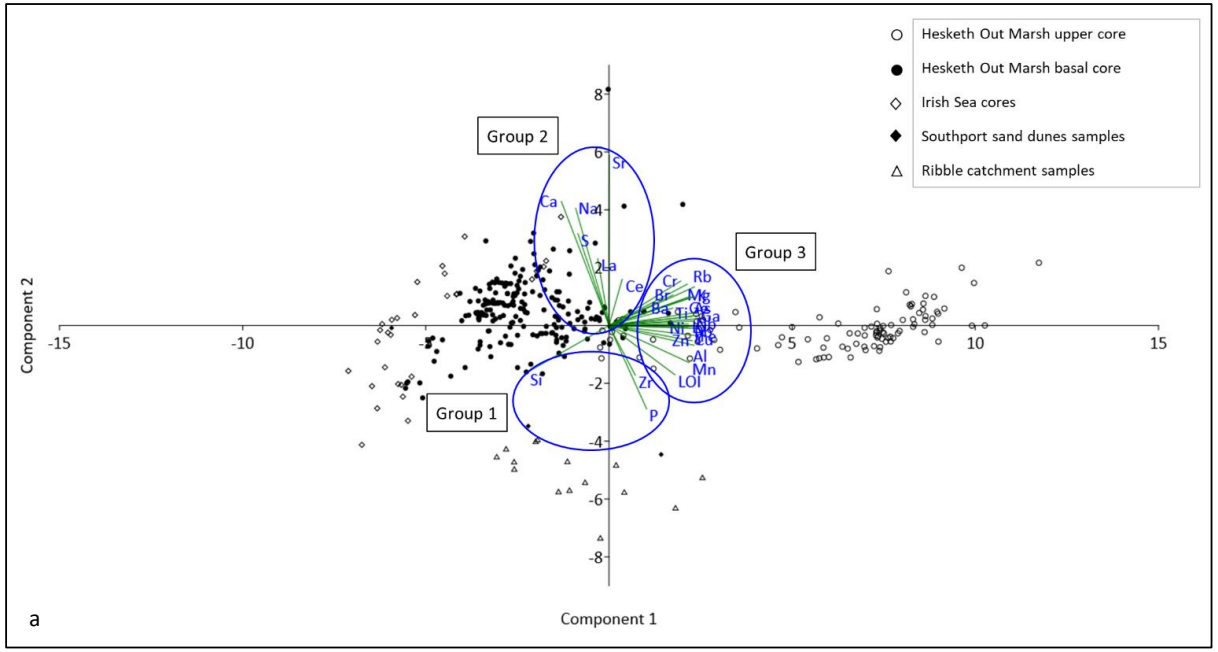
Results: paleoenvironmental reconstruction

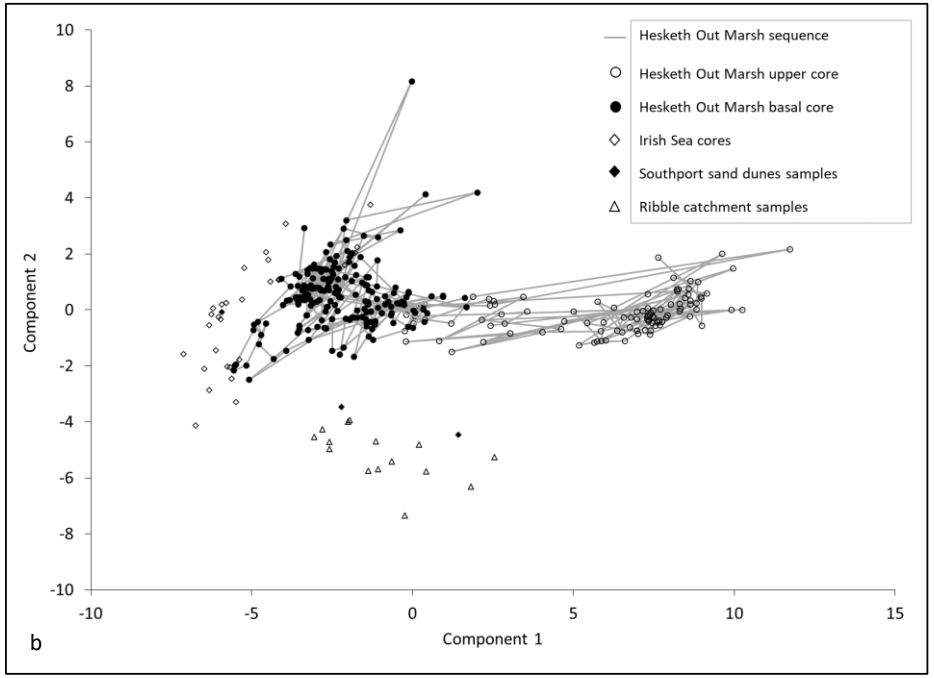
- Rapid accretion followed by a slower deposition.
- The accretion is currently a magnitude higher than sea-level rise (c.a. 2 mm/yr) meaning that it allows the marsh to survive.
- The rapid accretion precedes the beginning of embankment construction (c.a. 1810).
- Embankment cannot be responsible for a faster accretion.
- Could it be the natural evolution of the system?



Results: paleoenvironmental reconstruction

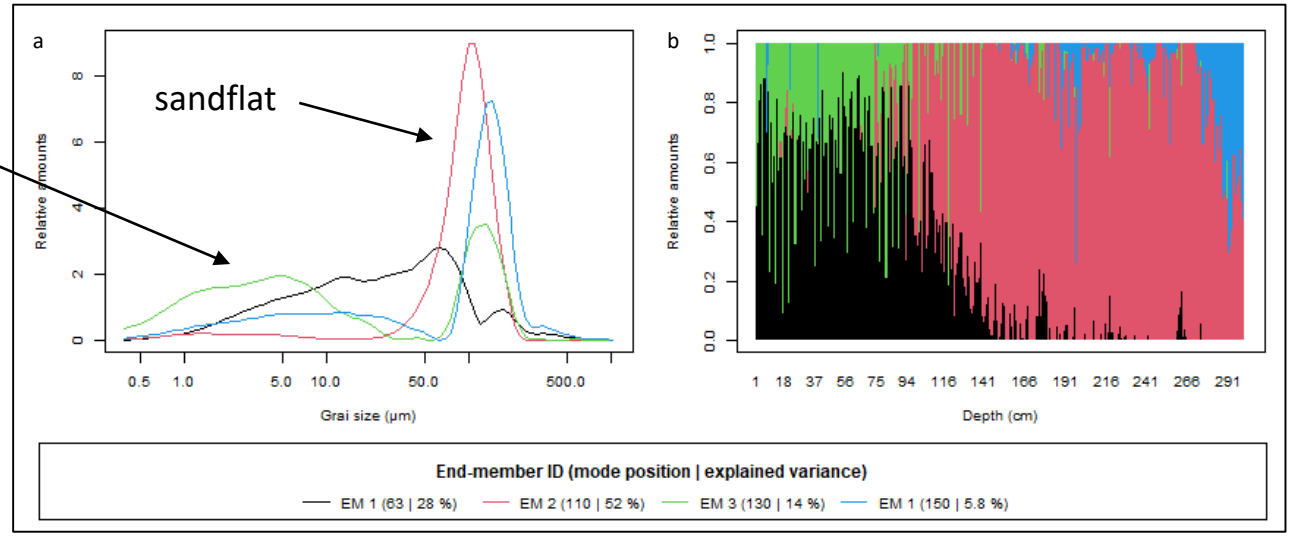
- Geochemistry correlates sediment supply to the marsh platform with sediments from the bed of the Irish Sea.
- The Irish Sea is characterised by high quantity of mobile sediment, legacy of the Irish Sea Glacier.
- Could the fast accretion be naturally driven by a high sediment supply to the system and the trend resemble the natural evolution of a marsh system?

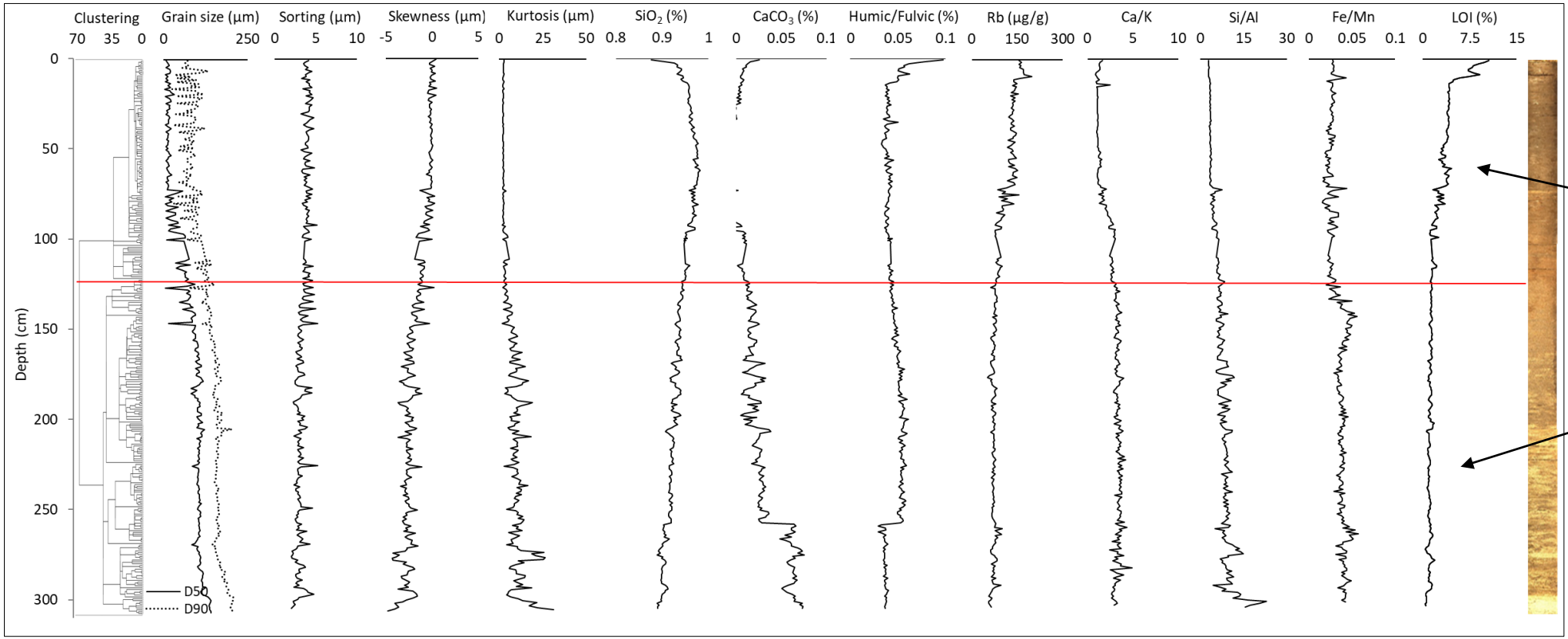




Results: paleoenvironmental reconstruction

- Multi-proxy down-core analysis shows gradual evolution of the system from sandflat to mudflat and salt marsh.
- Correlation between evolution of the marsh system and shift in accretion rate.





mudflat/salt marsh

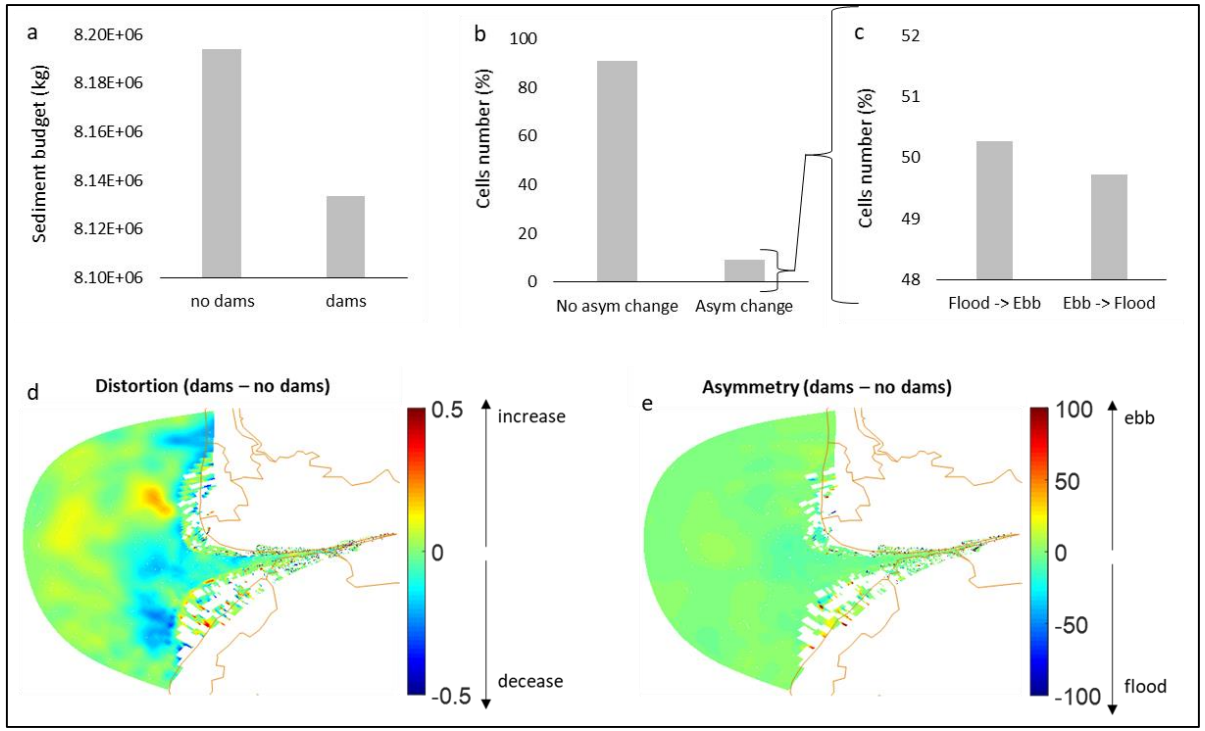
sandflat

Results: modelled scenarios

- After one year of simulation, the increase in sediment budget on Hesketh Out Marsh platform is higher for the scenario where no embankments are present.

- When embankments are added, about 10% of the domain is affected by a change in asymmetry. More than 50% of this change involves a shift from flood dominated to ebb dominated cells, while a shift from ebb dominated to flood dominated cells involves less than 50% of this change.

- An overall intensification of ebb dominance and weakening of flood dominance favours sediment export.



Key points

- High sedimentation rates support mudflat and salt marsh resilience to sea-level rise
- The construction of embankments can promote sediment export out of estuarine systems
- Natural sediment supply from the ocean can be fundamental for the survival of estuarine marshes

References

Pannozzo N., Smedley R., Chiverrell R., Carnacina I., Leonardi N. (2021). Influence of sediment availability and embankment construction on salt marsh resilience to sea-level rise. *Journal of Geophysical Research: Earth Surface*, In review.


Questions?