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Impact of time-series data resolution on simulating shoreline change

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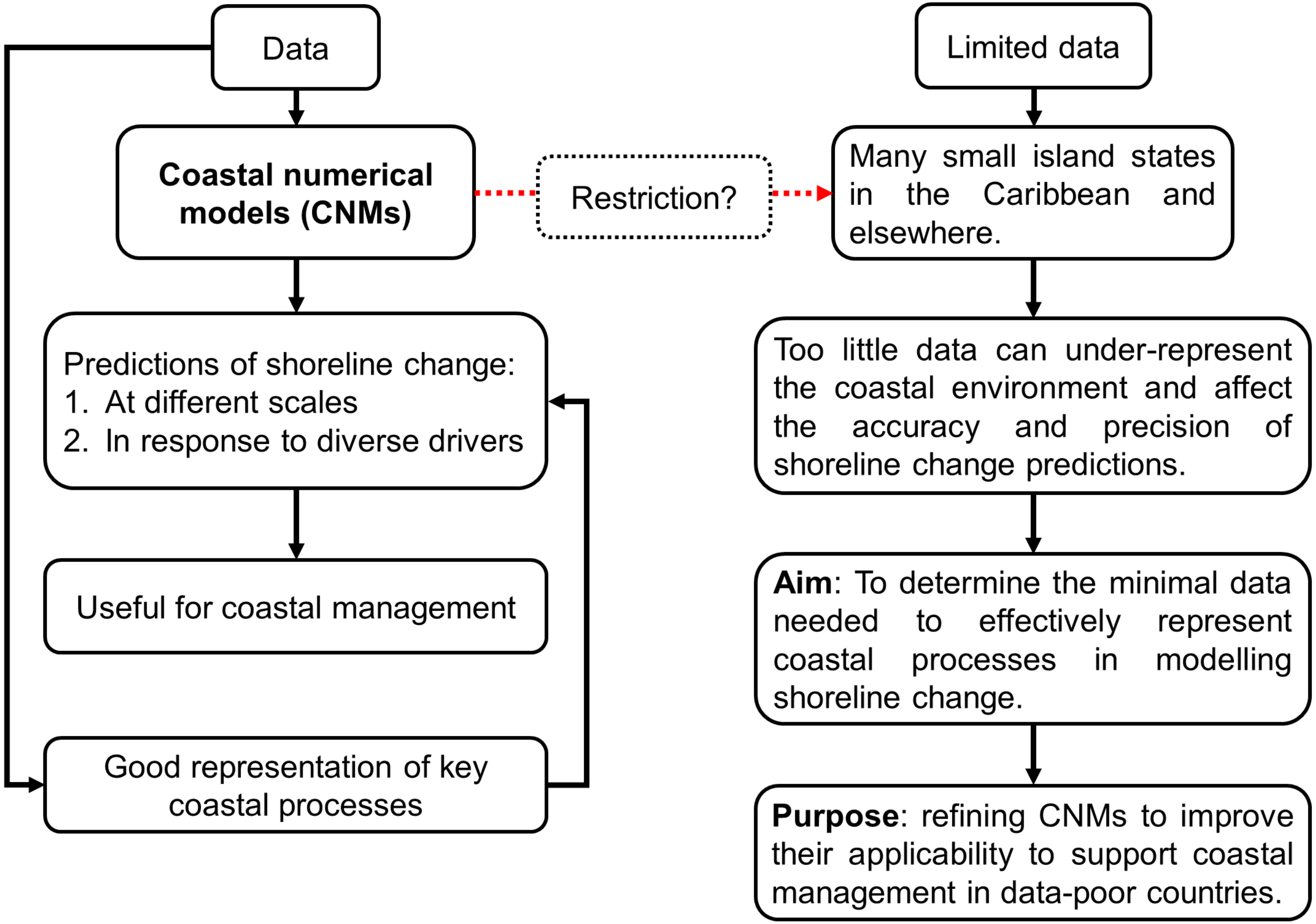
Research background



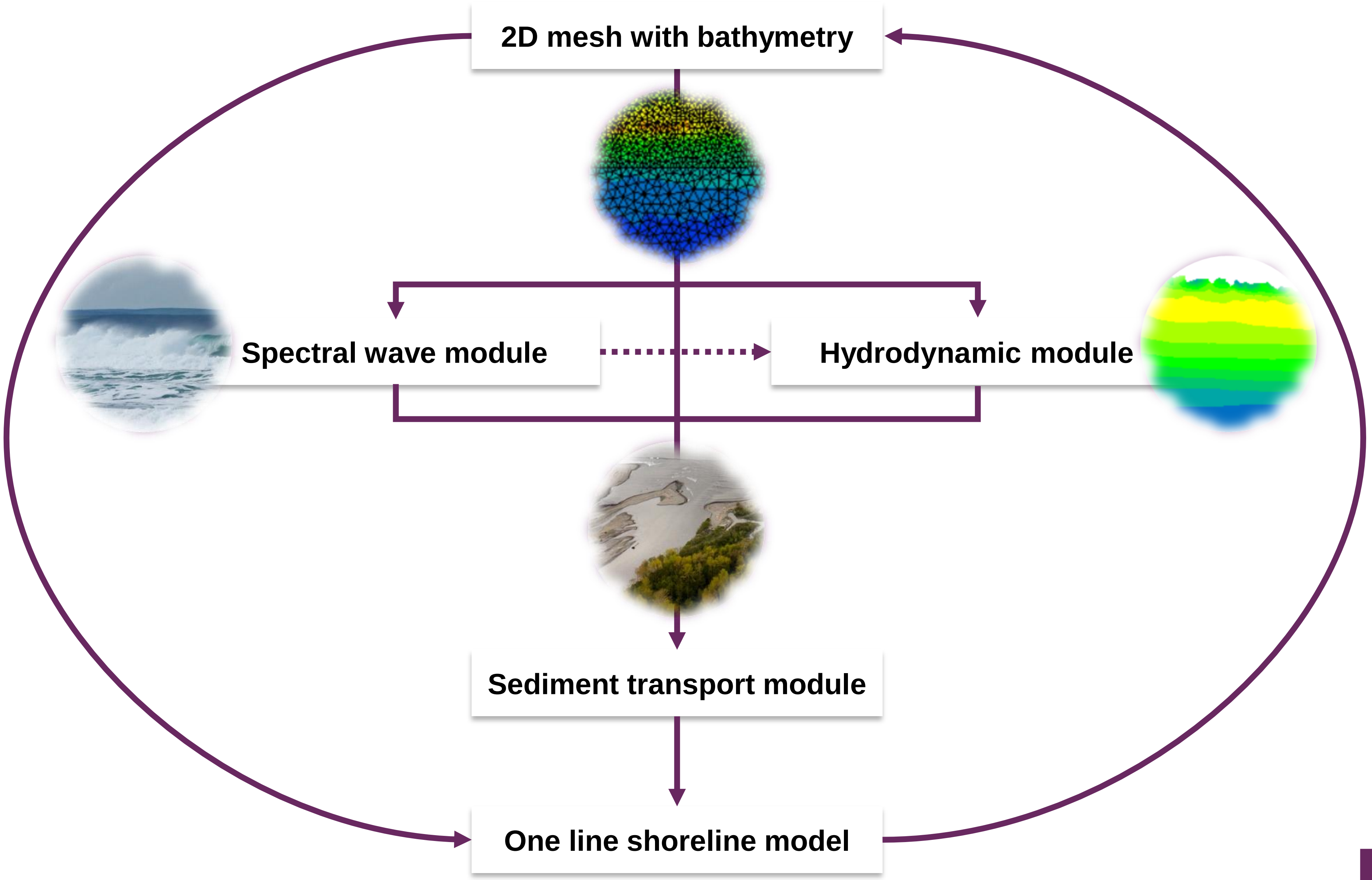
Study site and data

Long Beach Barrier Island, New York

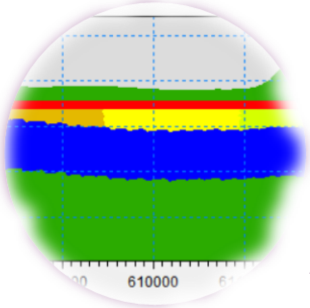
We obtain coastal relief and processes data (i.e. currents, tides, waves, and wind) from the National Oceanic and Atmospheric Administration (NOAA) online data repositories.

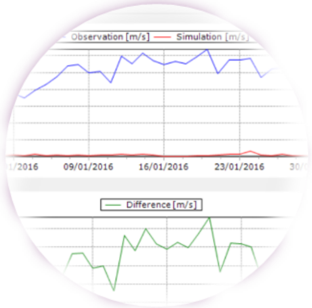
Model DEM	**Shoreline**	**Currents**	**Tides**	**Wave climate**	**Wind**
Source: NOAA NCEI *Resolution*: 3 m *Horizontal Accuracy:* 0.61m *Vertical Accuracy*: 0.02 m *Datum*: MHW	MHW	*Source*: NOAA *Station ID*: n03020 *Resolution*: 6-minute	*Source*: NOAA *Station ID*: 8531680 *Resolution*: 6-min *Datum*: MHW	*Source*: NOAA NDBC *Station IDs*: 44065, 44066, 44097 *Resolution*: 1-hour	*Source*: NOAA *Station ID*: 8516945 and 8519532 *Resolution*: 6-min

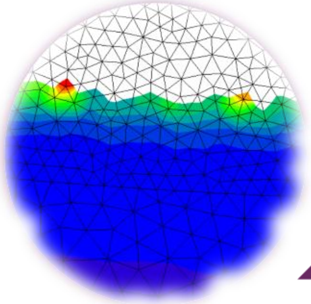
Model description: MIKE 21 Coupled Model FM

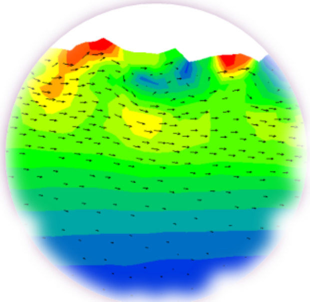


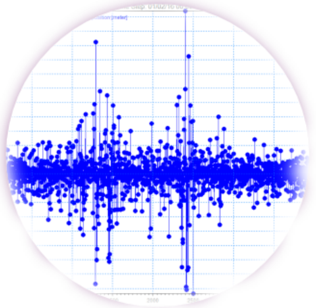
Methodology











Model development

- We develop a 2D coupled wave, flow, and sediment transport model, relative to mean high water.

Calibration

Mesh Independence

Simulations

Analysis

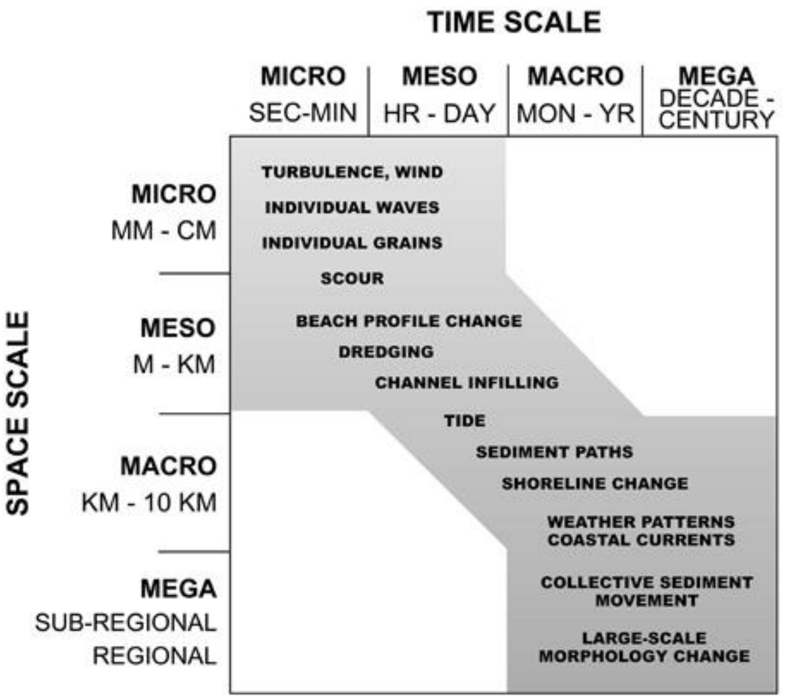
Methodology: Model development relative to scales of relevance

We focus on large-scale coastal evolution modelling (i.e. engineering time-scales).

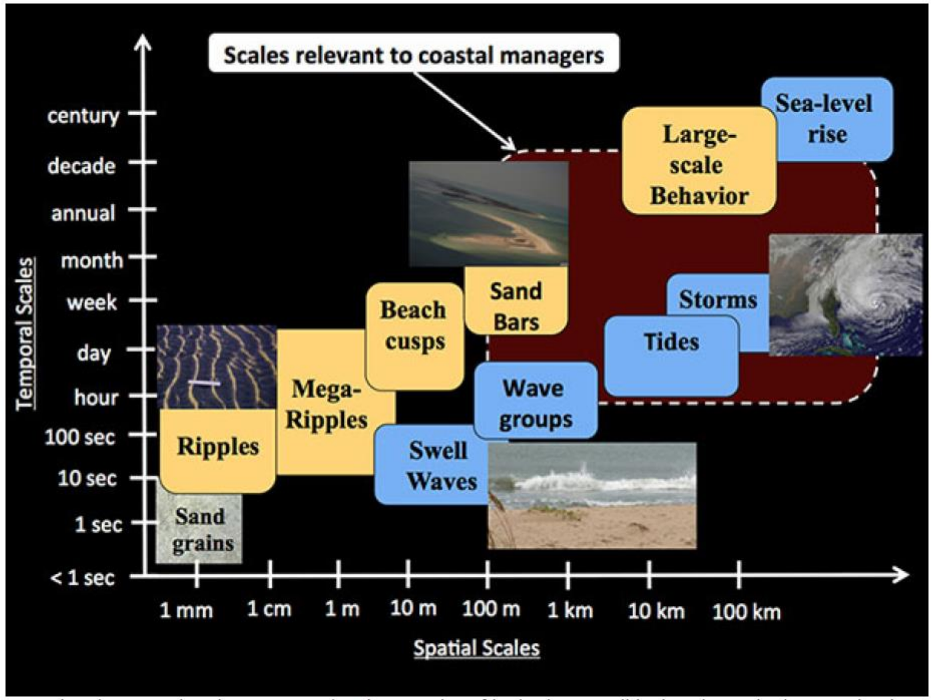
- Timescales of interest: decadal
- Spatial scales of interest: ≥ 10 km

→ Most relevant to coastal management

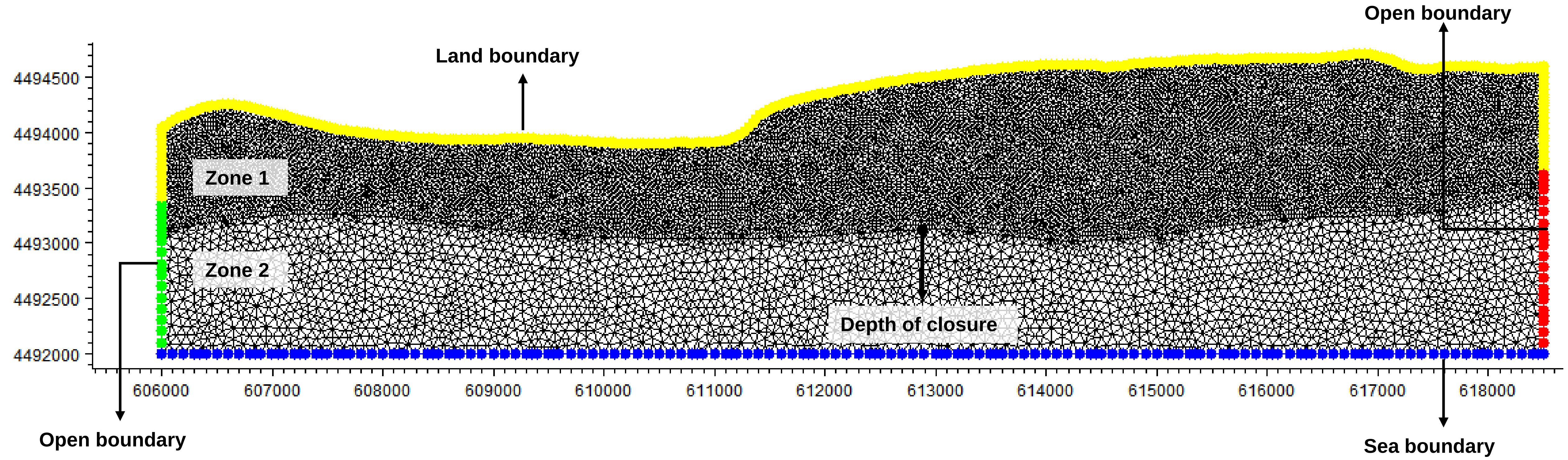
Length scale of key coastal processes of relevance (currents, tides, and waves): 100 m to > 10 km.



Gallop et al. (2015) modified from Larson and Kraus (1995)



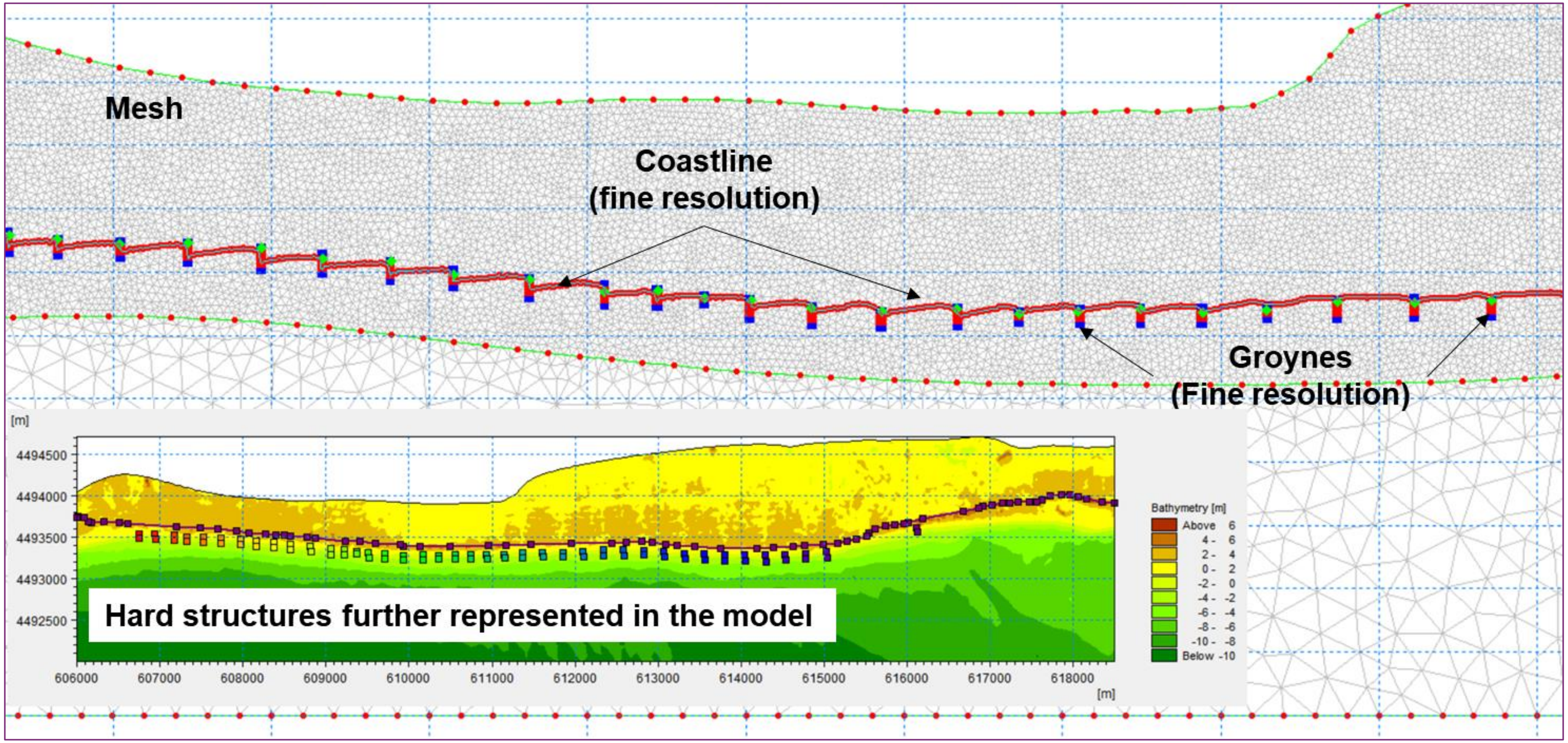
United States Geological Survey

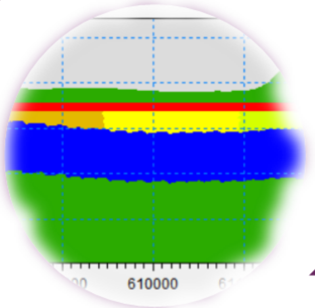


Key specifications:

- Zone 1 (Nearshore): Extending from the land boundary to closure depth (Resolution: 25 m).
- Zone 2 (Offshore): Extending from the closure depth to the seaward boundary (Resolution: 70 m).
- Seaward boundary: Tides and wave conditions entered here.
- Horizontal datum: WGS 84 in metres
- Vertical datum: MHW in metres
- Depth of closure: 5.84 m below MHW

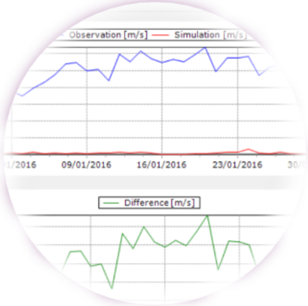
- We adopt a sub-grid modelling approach.
- We keep important small-scale features, with a horizontal dimension smaller than the element sizes used in the computational mesh, at a fine resolution.





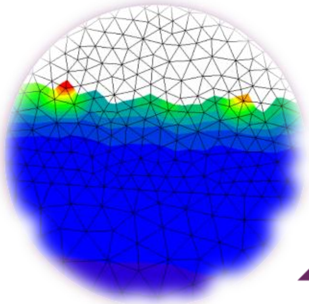
Model development

- We develop a 2D coupled wave, flow, and sediment transport model, relative to mean high water.



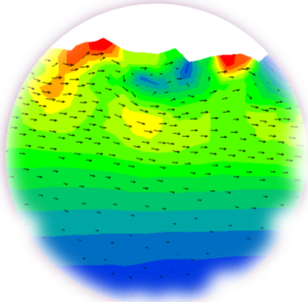
Calibration

- We calibrate the model using bed resistance, eddy viscosity, and ripples against observations of shoreline position, current speed, and bed levels.



Mesh Independence

- We perform a mesh independence study to find a suitable grid size to model shoreline change.



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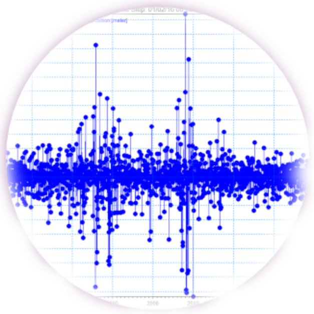

Analysis

Methodology: Calibration and mesh independence study

- Main parameters normally used in the calibration of a shoreline model:

  - Bed resistance
  - Eddy viscosity
  - Ripples
  - Coastal profile
  - Wind friction

  Bed resistance, Eddy viscosity, Ripples → Parameters used

- Standard rule applied: we tune all parameters during the calibration, but one at a time.
- We use a 2-year period for the calibration.
- We assess model calibration against observations of shoreline position, current speed, and bed levels.
- Following calibration, we simulate the coastal environment at the study site for a 2-year period (2014-2016) with varying nearshore resolution (range: 25 m to 65 m) to optimise the model.

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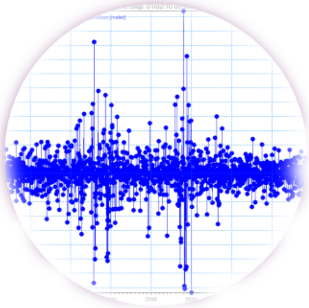
Selected grid size:
40 m (nearshore) x 70 m (offshore)



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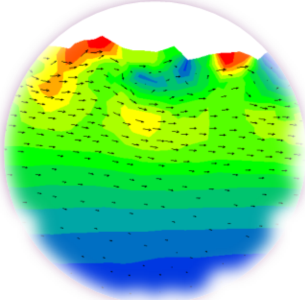
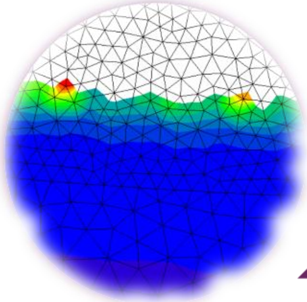


Simulations

- We simulate the coast at the study site for a 2-year period with the data resolution of tides, wind, and waves tuned one at a time following a stepwise calibration approach.



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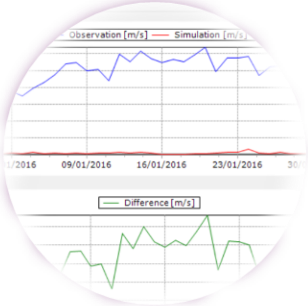

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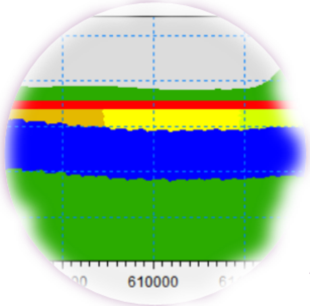


Model development

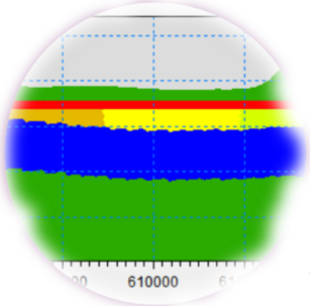
- We develop a 2D coupled wave, flow, and sediment transport model, relative to mean high water.

Methodology: Stepwise calibration approach outline

We tune the resolution of each coastal variable (i.e. tides, wind, and waves) one at a time. For example, the lowest tide data resolution, which produces acceptable model predictions, is used in simulations with varying wind data resolution and so on.

Variable	Tides	Wind	Waves
Model code/ Resolution	TS001/6-min	TS001-7/6-min	TS001-13/1-hr
	TS002/1-hr	TS008/1-hr	TS014/12-hr
	TS003/12-hr	TS009/12-hr	TS015/24-hr
	TS004/24-hr	TS010/24-hr	TS016/Weekly
	TS005/Weekly	TS011/Weekly	TS017/Constant
	TS006/Constant	TS012/Constant	TS018/No waves
	TS007/No tides	TS013/No wind	

Methodology



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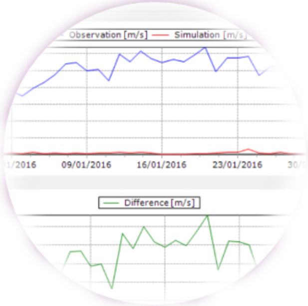

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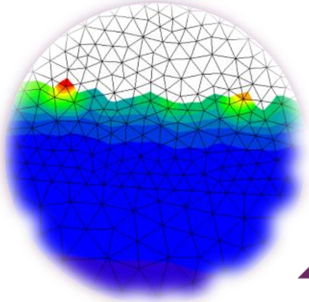

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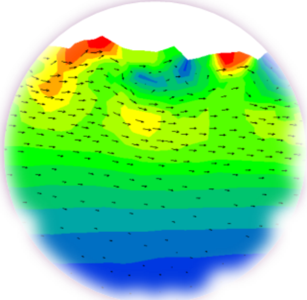

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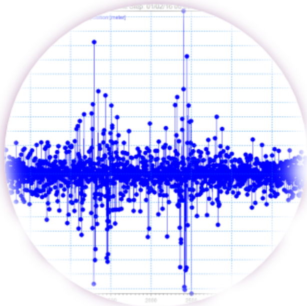
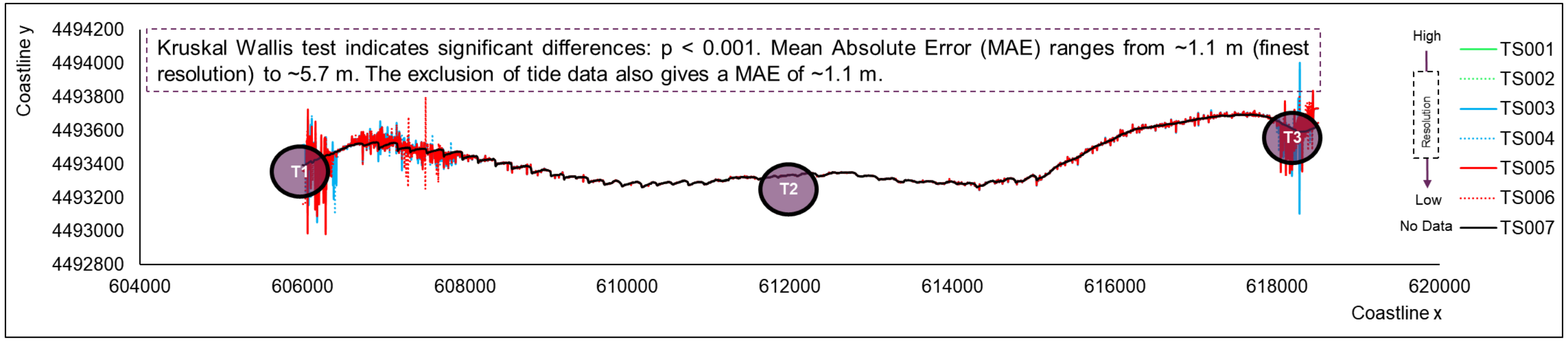


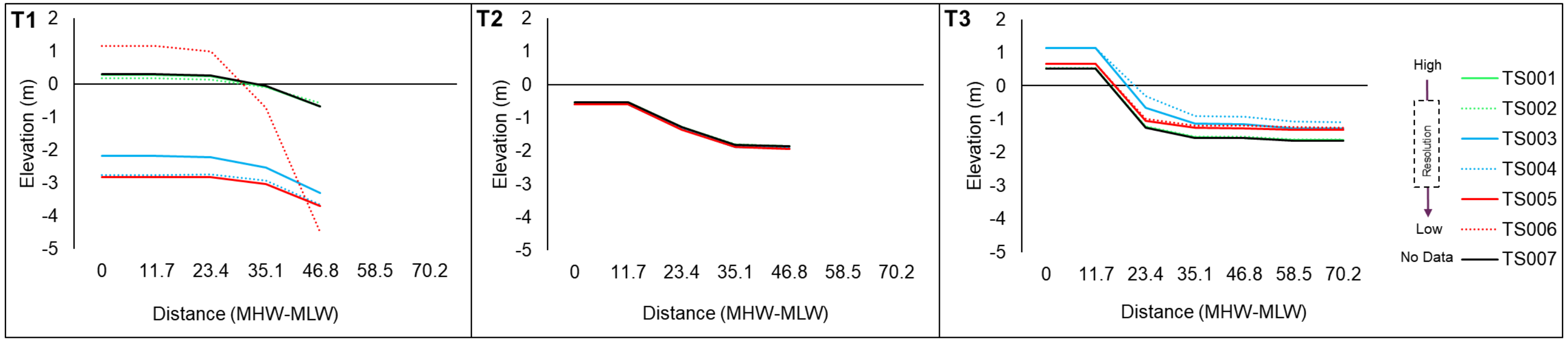
Analysis

- We quantify the impact of coastal processes time-series data resolution on shoreline position, bed level, and sediment transport predictions.

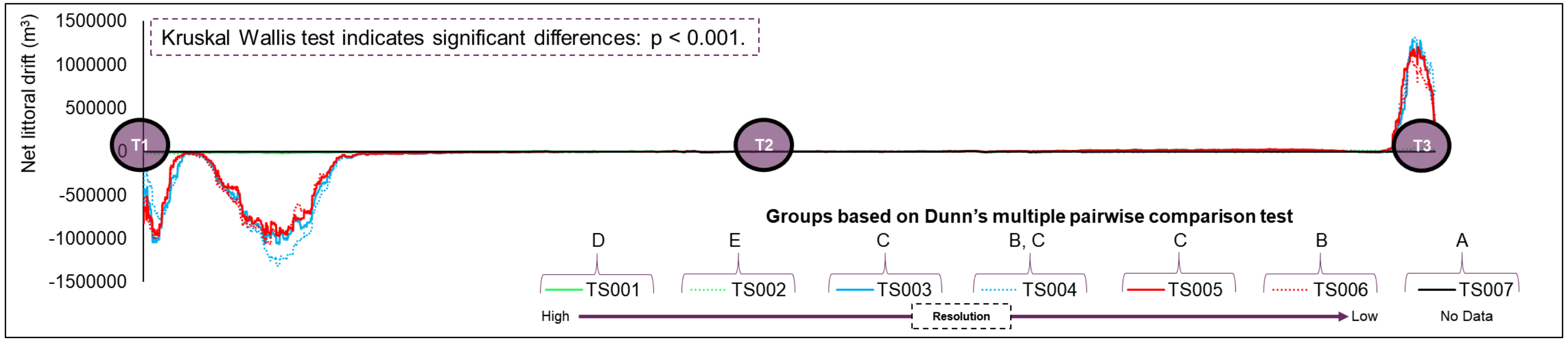
Results: Impact of tidal resolution on modelling shoreline change



A: Shoreline prediction relative to tidal data resolution.



B: Bed level prediction relative to tidal data resolution. TS001 and TS007 gives the lowest MAE (i.e. ~0.5 m).

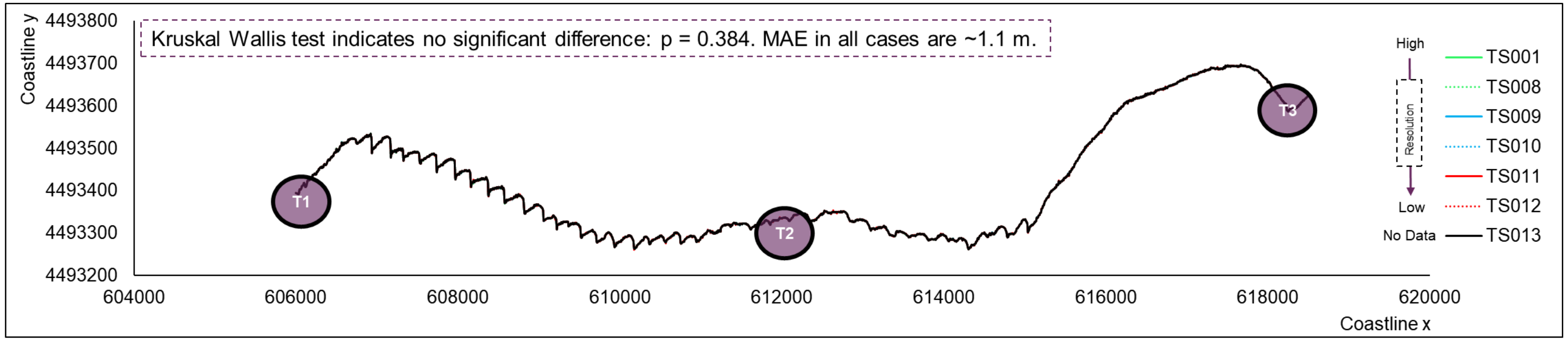


C: Sediment transport prediction relative to tidal data resolution.

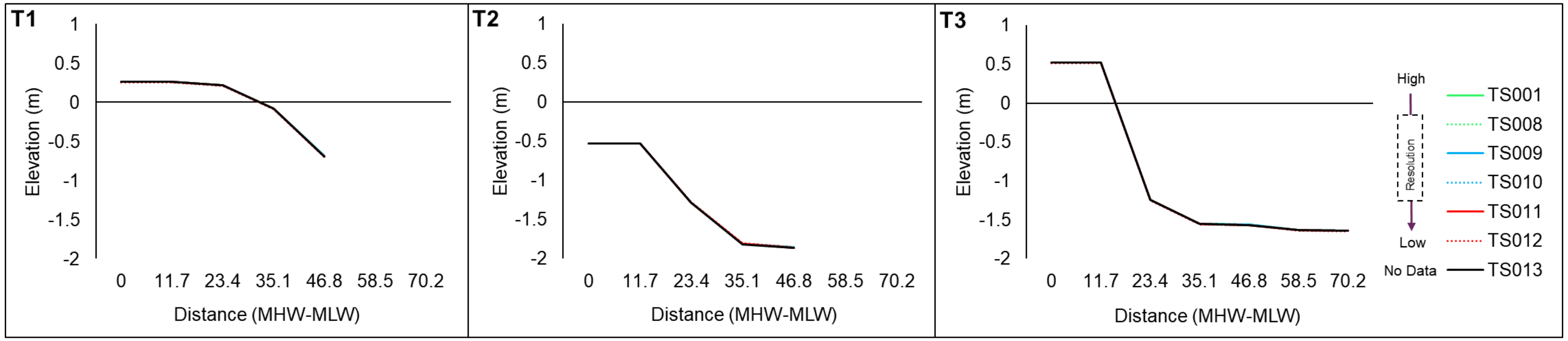
Key observations:

- Shoreline and bed level prediction worsens with tide data resolution > 6-minute intervals.
- The exclusion of tide data gives good results.
- Kolmogorov-Smirnov test indicate **no significant difference** in water surface levels generated from tide and wind data ($p = 1.0$).
- Net littoral drift prediction varies with tide data resolution.
- Overall, the model is sensitive to tide data resolution, with the finest resolution giving the best results.

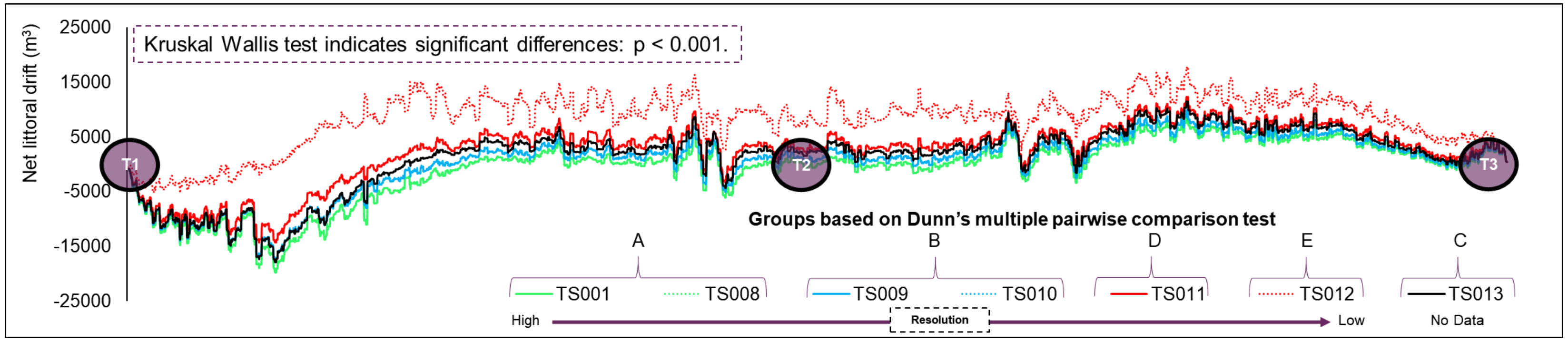
Results: Impact of wind data resolution on modelling shoreline change



A: Shoreline prediction relative to wind data resolution.



B: Bed level prediction relative to wind data resolution (Kruskal Wallis test indicate no significant change: $p = 1.0$).



C: Sediment transport prediction relative to wind data resolution.

Key observations:

- Wind data resolution has a greater impact on net littoral drift predictions.

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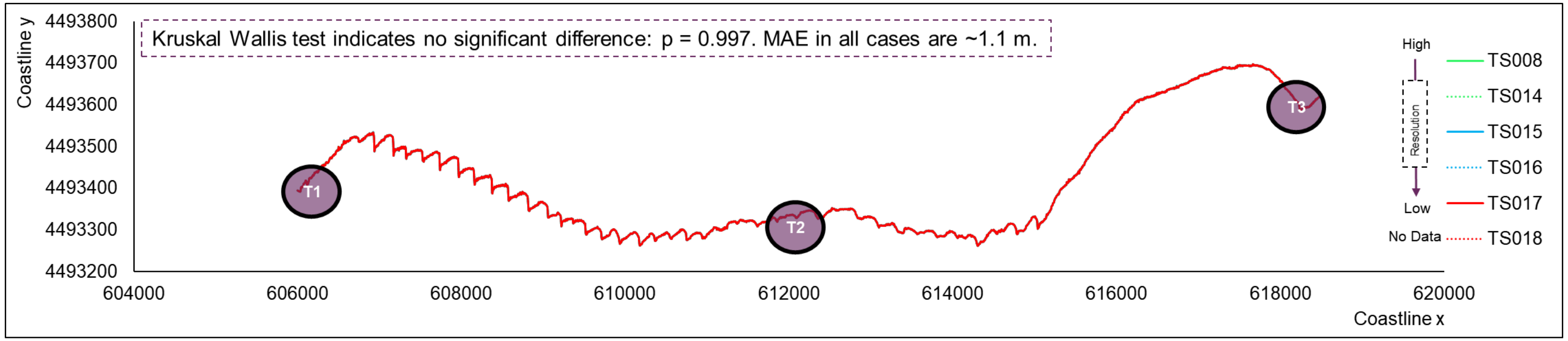
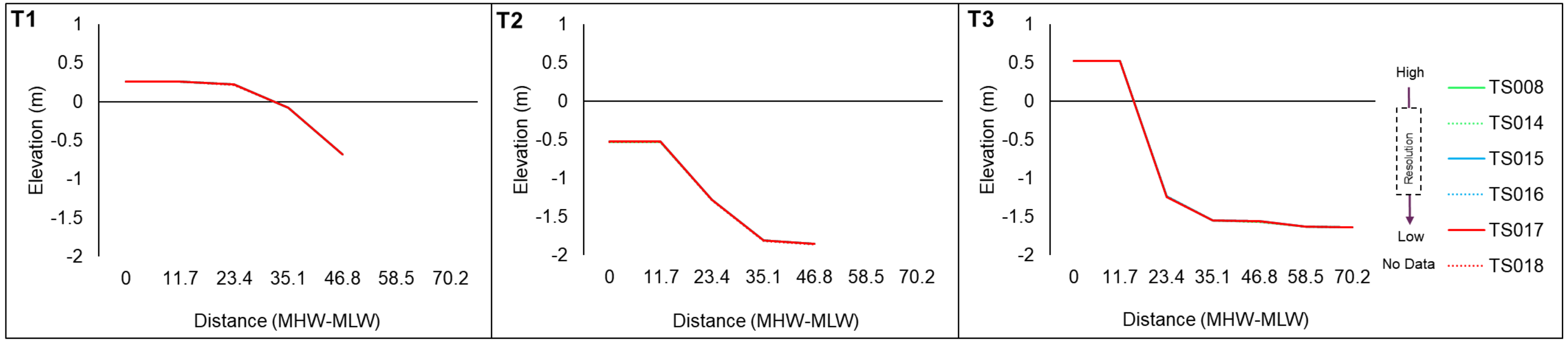
Can affect shoreline and bed level outputs over longer simulations.

- Wind data ≤ 1-hour intervals has no significant impact on model estimates of net littoral drift.

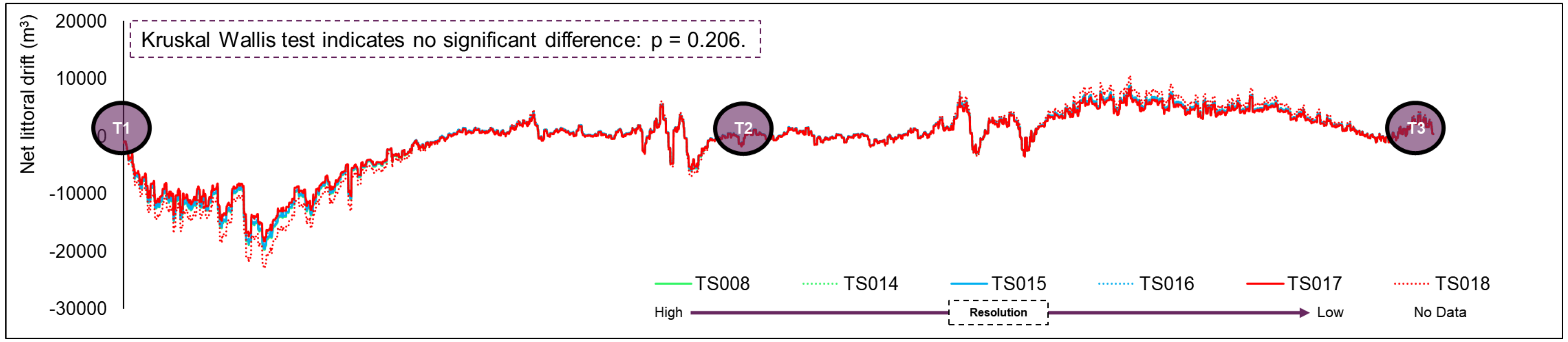
Results: Impact of wave data resolution on modelling shoreline change



A: Shoreline prediction relative to wave data resolution.



B: Bed level prediction relative to wave data resolution (Kruskal Wallis test indicates no significant change: p = 1.0).



C: Sediment transport prediction relative to wave data resolution.

Key observation:

Despite no significant changes, there are clear spatial differences in net littoral drift predictions with the exclusion of wave data.

Data on the **average wave conditions** is **at least** needed to effectively model shoreline change.

Preliminary conclusions

To effectively simulate shoreline change:

1. High tide data resolution is needed (e.g. 6-min intervals). In the absence of tide data, wind data is sufficient for producing acceptable water surface levels.

2. Wind data ≤ 1-hr intervals is sufficient.

3. Data on average wave conditions is acceptable.

Model comparison
Exact trends are found with model application to Santa Monica, Southern California.

Wider implications
Countries devoid of high-resolution tide and wave data (e.g. Caribbean island states), can use CNMs to inform coastal management, if hourly wind records and data on general wave conditions are available.

Thank you…

Questions or comments?

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