Predicting port sedimentation and navigational depths on medium/longterm timescales

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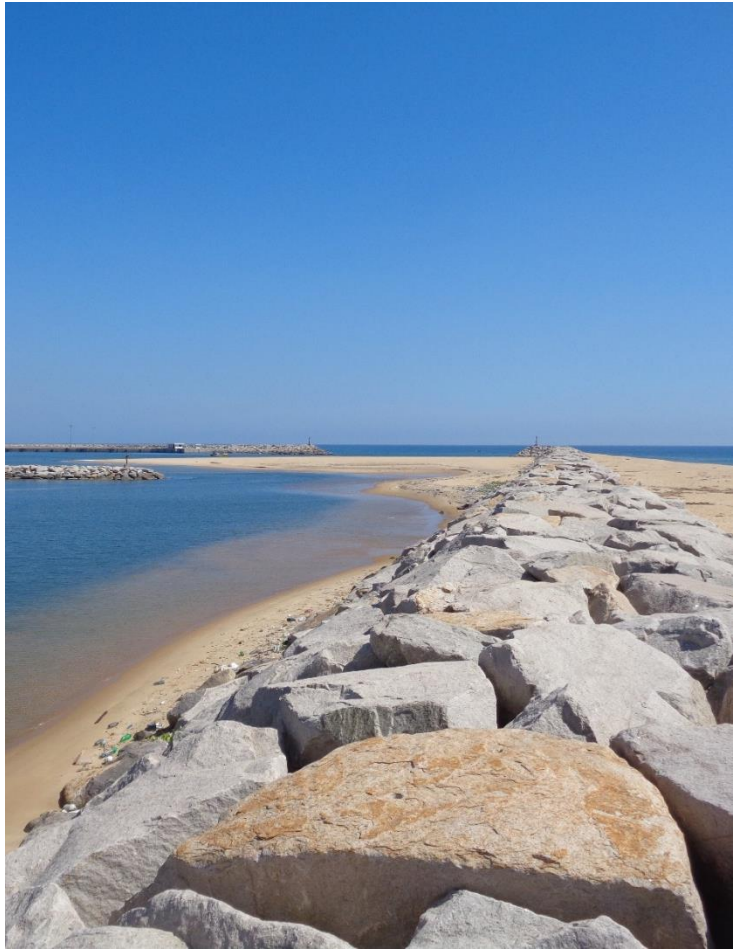
Agenda

- Port sedimentation
- Morphological modelling
- Modelling strategy (Hvide Sande, Denmark 2009)
- Modelling strategy (example of port sedimentation, 2018)
- Conclusions

Port sedimentation

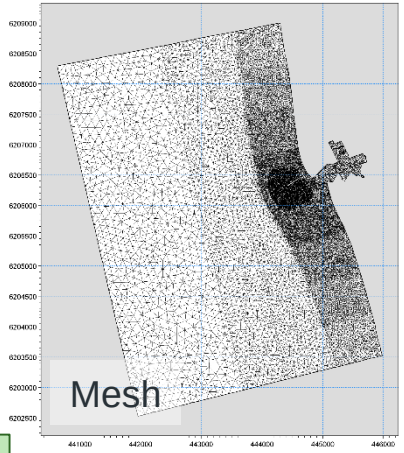
- Sandy coastal zone: Potential for enormous masses of sand, which are constantly or episodically worked and re-worked by waves and currents
- Sedimentation in calm waters or areas with locally lowered bed
  - Port basins
  - Approach channels
- Risk for safe navigation
- Restricts the vessel size that the port can accommodate

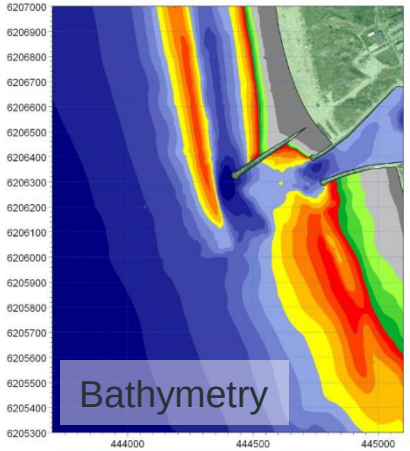
- Mitigations
  - Maintenance dredging
  - Optimise port design to reduce/avoid sedimentation

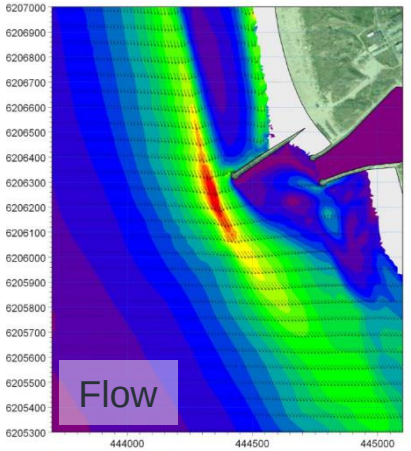


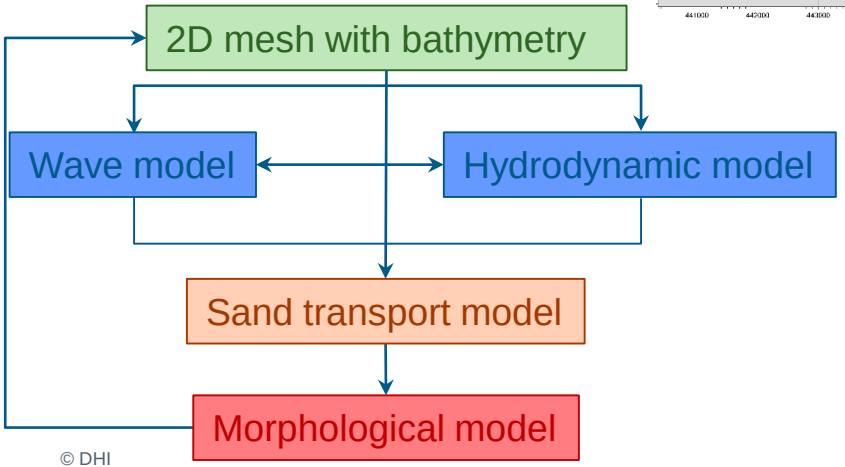
2D morphological modelling – MIKE 21 Coupled Model FM

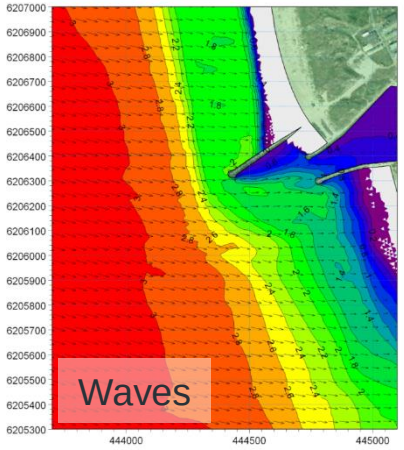
- Bed changes from divergence of the sand transport field
- Bed changes feedback on the waves and flow

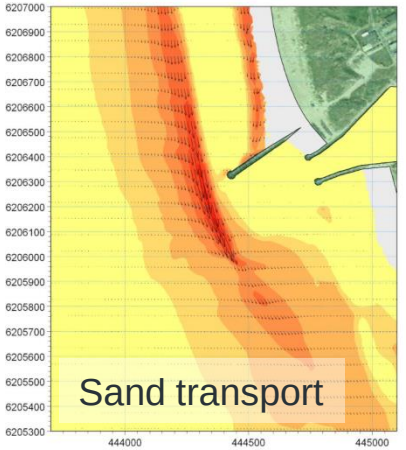






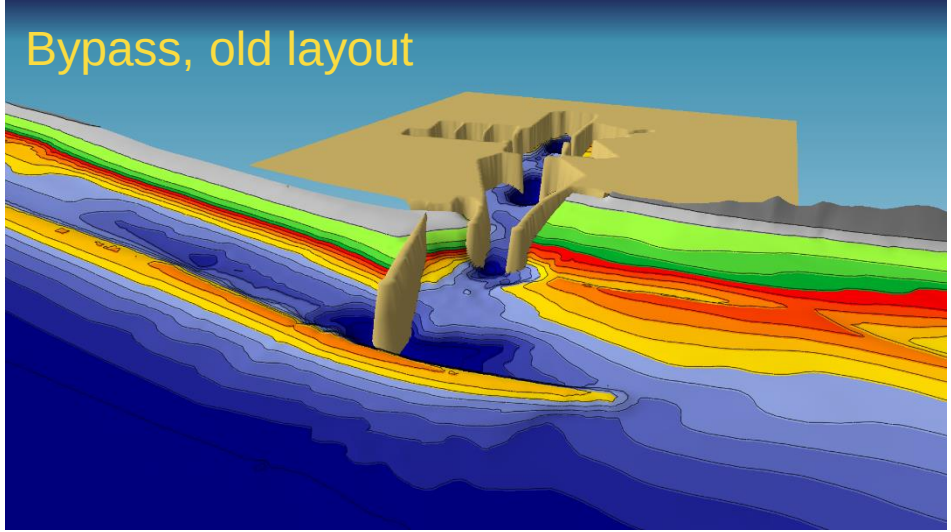


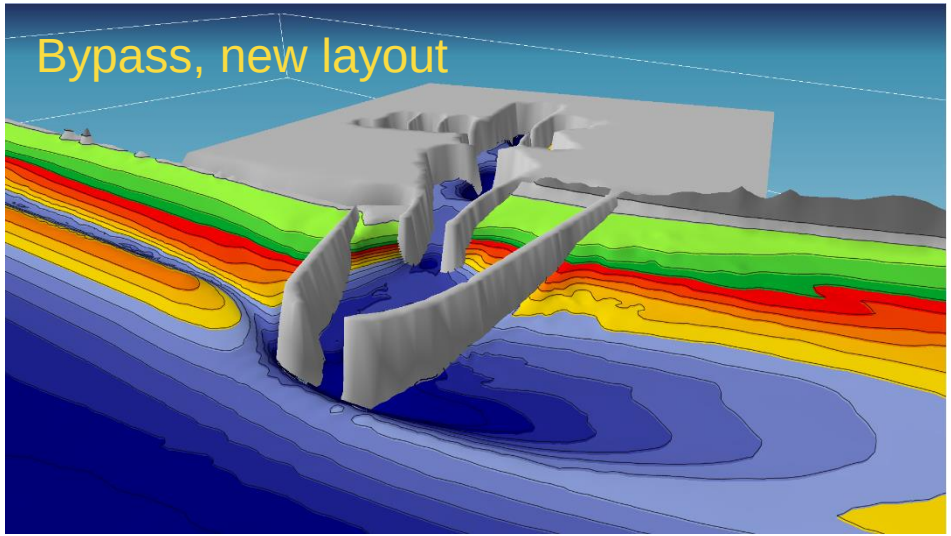




Modelling strategy, 2009

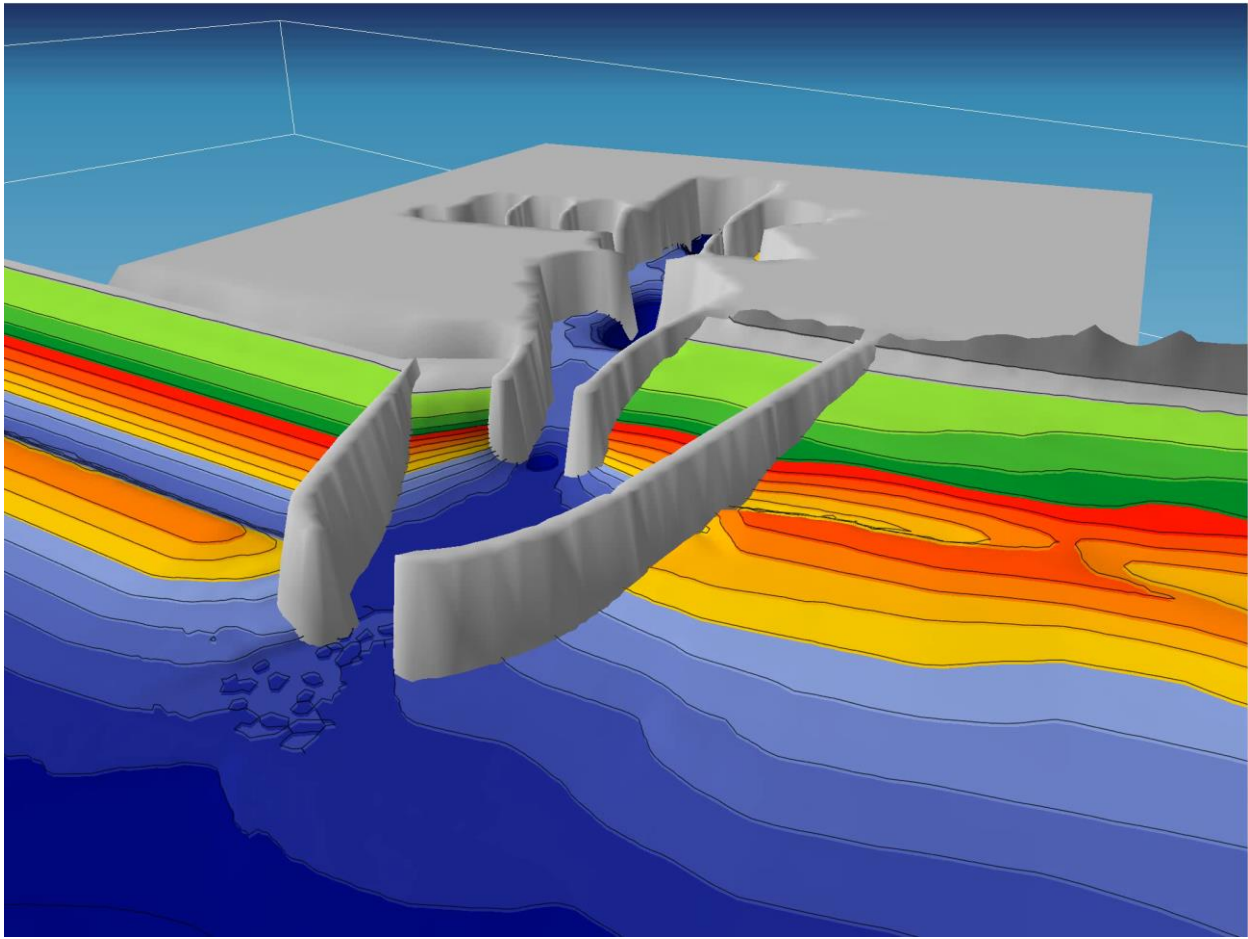
- 2D morphological model (active in the entrance)
  - Speedup by simulating events with Hs>1.0m (30 days represent 1 year)
  - Updrift bathymetry is fixed (based on analysis of historic profiles)
  - No longterm analysis because updrift bathymetry is fixed
  - Calibration and validation against two storm events
- Strength
  - Use the model to test different scenarios to optimise navigation depth





Modelling strategy, 2009

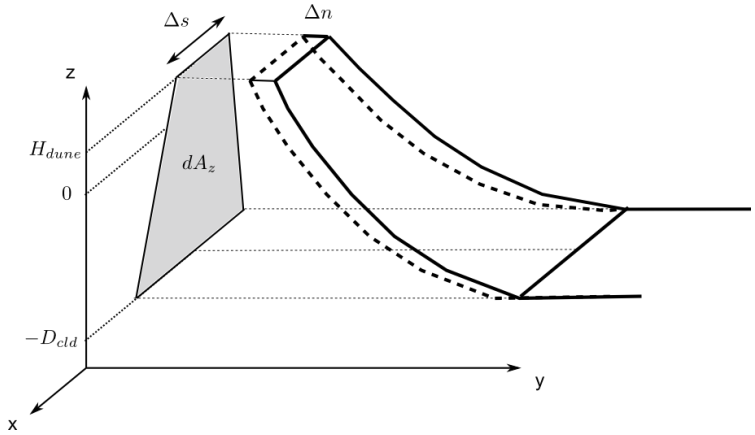
- Guide the morphology by fixing the updrift morphology
- Strengths:
  - Ensure the right sediment supply to the port area
  - Guide the shape of the bar
- Challenges:
  - No variation in updrift bathymetry
  - Longterm effect: gradual filling of updrift sand fillet
  - Downdrift profile degenerates



Shoreline modelling in MIKE 21 Shoreline Morphology FM

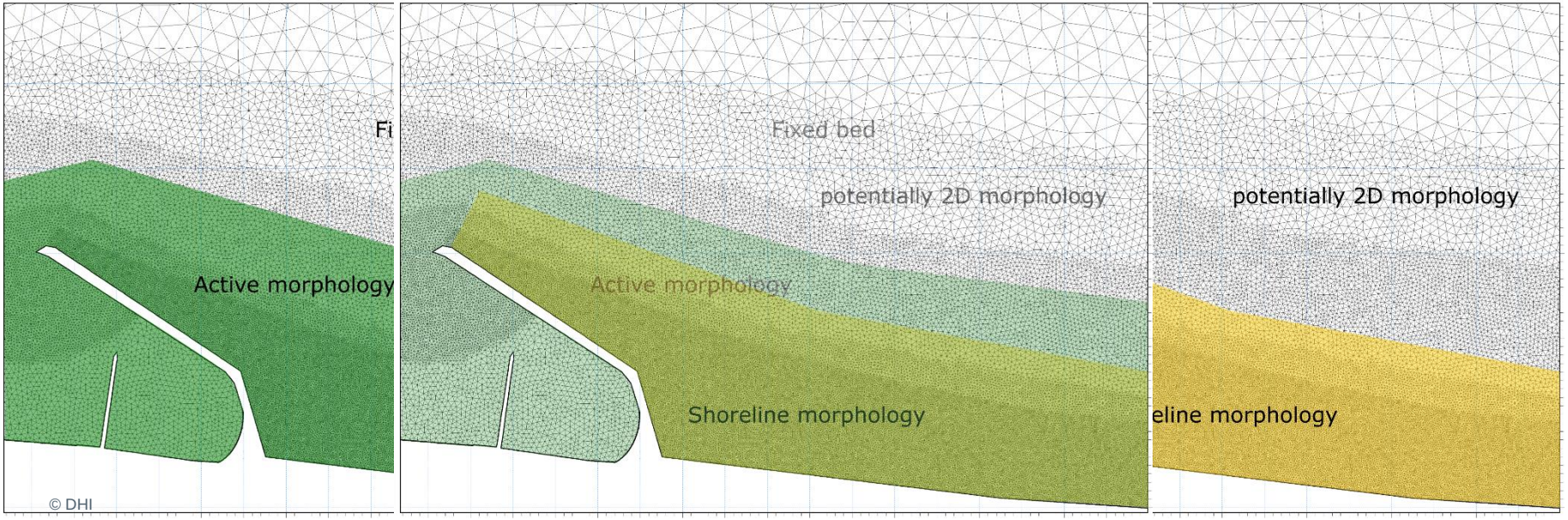
- Shoreline morphology in MIKE 21 FM: Apply the 1-line morphological principle to a coastal area model
  - The shape of the coastal profile is prescribed: Bed level is a function of the distance to the coastline
  - Erosion/Deposition is imposed by shifting the coastline onshore/offshore by integrating volume changes from the 2D calculation

- The Shoreline response can be used in a part of the model domain
- Ordinary 2D morphological response can be used in other parts of the model domain



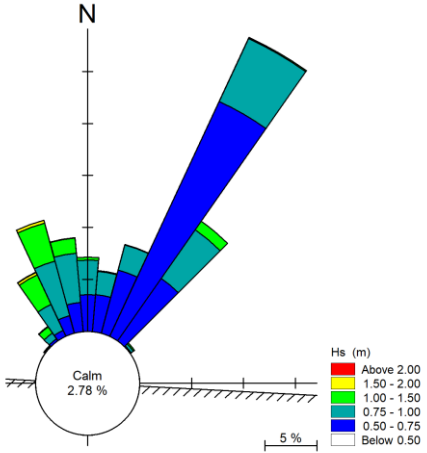
Modelling strategy, 2018

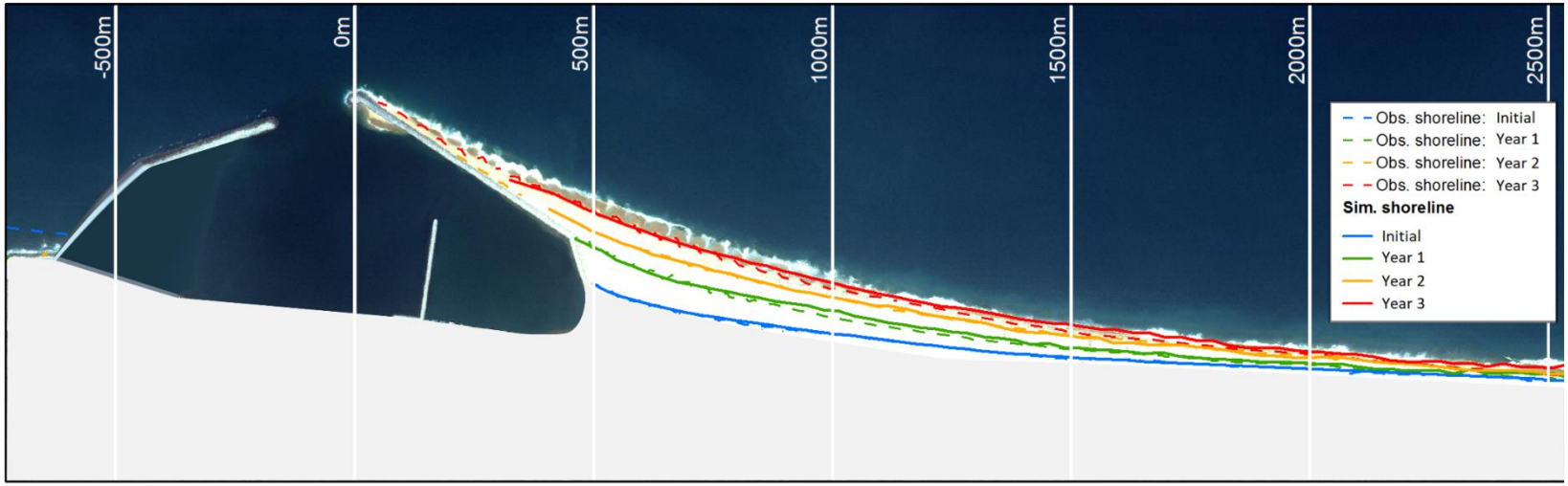
- Use 1-line morphology along open beaches
- Use 2D morphology in areas where the expected reponse is of 2D nature
- The area with 1-line morphology acts as a dynamic boundary condition for the 2D areas
- Two maps: 1) map with active morphology, 2) map with 1D morphology



Validation

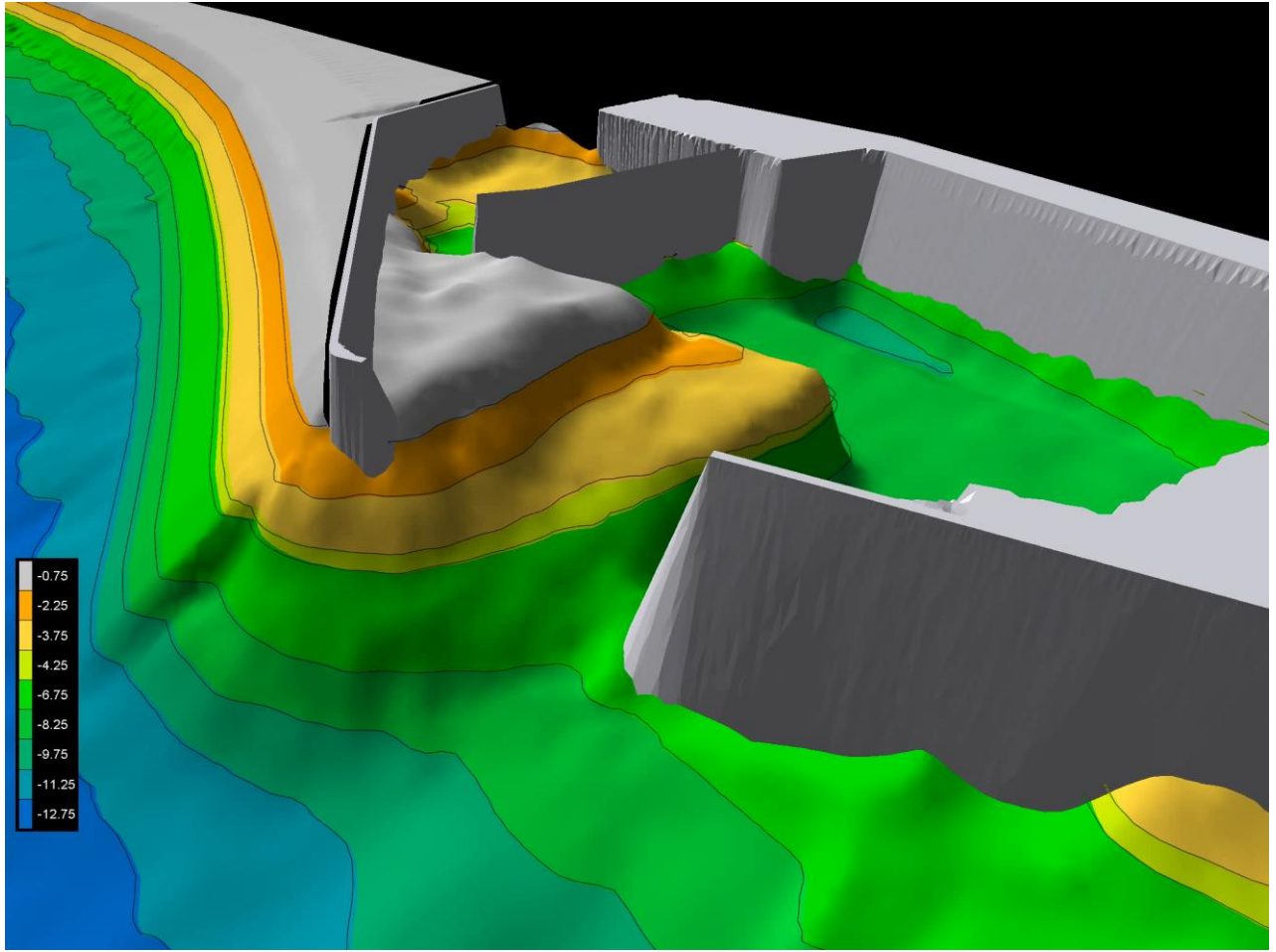
- Medium-term updrift sand accumulation
- Monsoon dominated coast
- Resulting transport towards west. Strong seasonal signal in transport direction
- Satellite image analysis used to confirm cyclic behaviour and gradual deposition





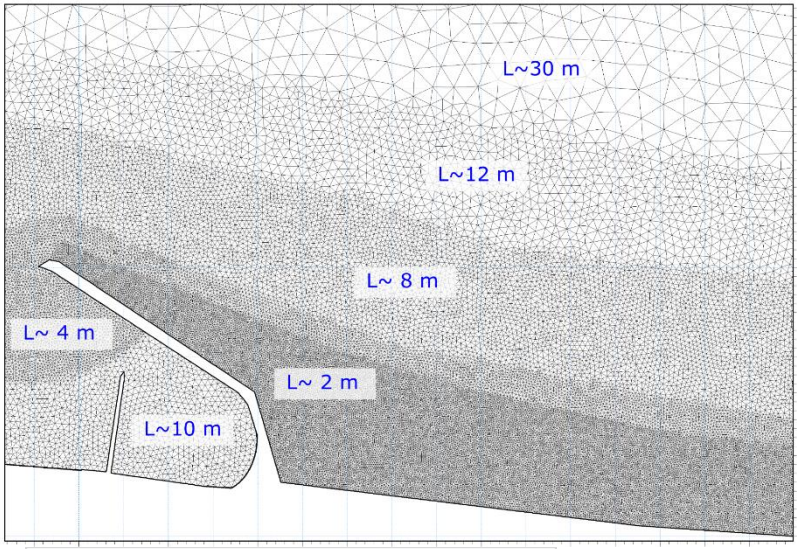
Modelling strategy, 2018

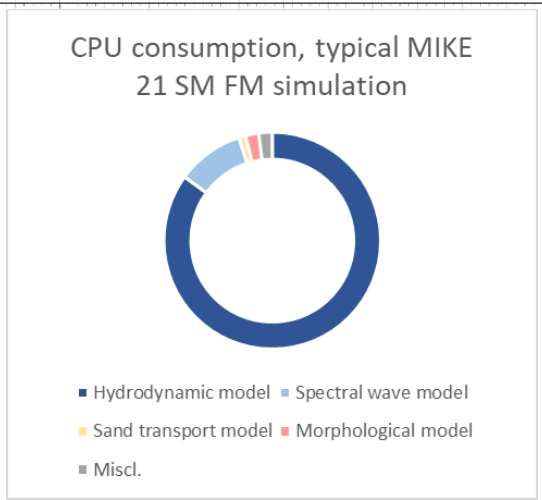
- Guide the morphology by prescribing the shape of the updrift profile
  - 1D morphology along open coast
  - 2D morphology in more complicated areas
- Schematised wave climate
- Applicable for longterm predictions (decades)



Computational performance

- Model calculation are done on an unstructured 2D mesh (~170,000 elements)
- Very fine mesh resolution to resolve littoral transport area
  - Predominant waves: ~0.5 – 1.0 m
  - Steep active profile: ~ 1/10
  - The seaward limit of the fine area is determined by the most advanced shoreline to be modelled
- CPU challenges approached by:
  - Schematic wave climate (10 sea-states)
  - Quasi-stationary HD solver

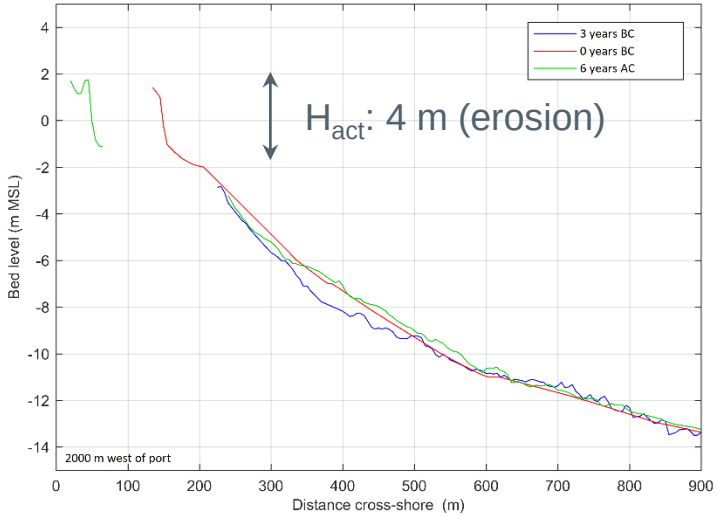


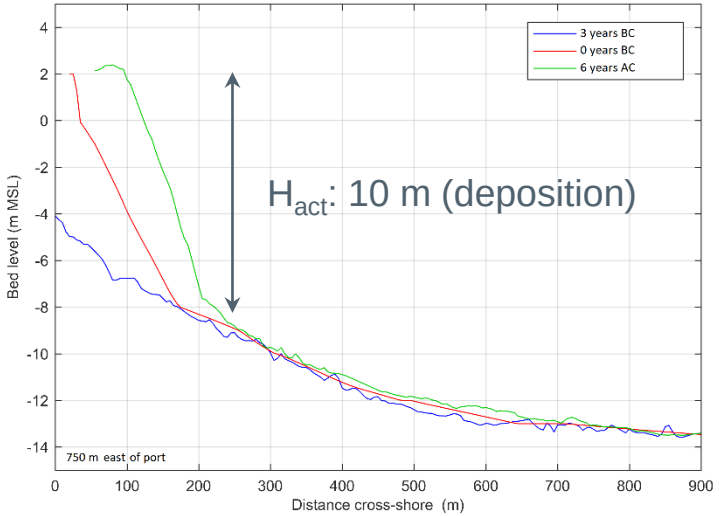


Varying closure depth

- Deposition along east breakwater: Avalanching type of bed changes below ”closure depth”
- Height of active profile during erosion is much smaller
- Hysteresis effect on shoreline changes:
  - Slow advance during build-up of sediment reservoir below -2 m
  - Fast advance/retreat where sand is already deposited below -2 m
- The 2D shoreline morphology model implements this behaviour

BC: Before port Construction
AC: After port Construction





Conclusions

- Port sedimentation is relevant on short, medium and long time scales
- 2D morphological models are typically used on shorter time scales, possibly with constrained freedom away from the area of interest
- If longterm effects are required, a traditional 1-line model is needed
- With MIKE 21 SM FM the 1-line concept is implemented directly in the morphological response of the 2D model
- 1D morphology has severe restrictions in the predictive capabilities for many complicated applications
- In future versions, the 1-line morphology can be seamlessly combined with traditional 2D morphology for improving the number of use cases
- The present study has shown how the 1D morphology is used as a dynamic boundary condition of the updrift shoreline to improve longterm predictions of port sedimentation

Questions?