Uncertainties in Long-term Shoreline Projections: Unravelling the Role of Sea-Level Rise and Equilibrium Modelling Assumptions

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Morphodynamics driven by several processes on different temporal/spatial scale (e.g. wave action, sea-level change, wind, etc.)
In a context of climate change, the spatial heterogeneity of sea-level rise, wave-climate change, time scales of adaptation, and vulnerability of coastal communities raises the need for shoreline projections with their related uncertainties that provide full support to risk-informed decision making process.

Hinkel et al., (2019)
Uncertainties

Uncertainties in modelling future shoreline change

Future climatic factors
(e.g. SLR and wave climate)

- Future climate change scenario
- Ice sheet melting dynamics
- Global climate circulation modelling

Modelling approach

- Model assumptions
- Calibration of free parameters
- Data availability

Little research effort has been made towards addressing uncertainties in shoreline projections.

Need to investigate the role and impact of the several sources of uncertainties in shoreline projections.
Method

Uncertainty propagation

Uncertain input variables

Uncertain shoreline projections at a given time

Shoreline evolution model

What is the relative impact of the uncertainties in the input variables on the shoreline projections?
Global Sensitivity Analysis
(Saltelli et al., 2008)

“How would the variance of the results change if we learned the true value of $x_1$?”

$1^{st}$ order Sobol’ index

$S_i^I = 1 - \frac{E[V(Y|x_i^*)]}{V_y}$
Method

Global Sensitivity Analysis (GSA)

1. Modelling input uncertainties through probability distributions of input stochastic variables

2. Propagation of uncertainties (probability distributions) through the model producing a distribution of uncertain model results

3. Assessment of the relative contribution of each uncertain input variable to the model results uncertainty

4. Uncertain Input Variables

5. Ensemble Shoreline Simulations

6. Global Sensitivity Analysis

D’Anna et al. (2020)
Case of study

Truc Vert beach (South-West France)
Case of study

General method

- Modelling input uncertainties through probability distributions of input variables
- Propagation of uncertainties (probability distributions) through the model producing a distribution of uncertain model results
- Assessment of the relative contribution of each uncertain input variable to the model results uncertainty

Truc Vert beach case

- Uncertain input variables:
  - Sea-level rise rate
  - Depth of Closure
  - Cross-shore model parameters

- 3000 Simulations of 90-years projections

- Calculation of 1st order Sobol’ indices time series

Scenarios

- 2x Equilibrium shoreline models
- 2x Future GreenHouse Gas concentration pathways

- ShoreFor RCP 4.5
- ShoreFor RCP 8.5
- Yates RCP 4.5
- Yates RCP 8.5
- Yates et al. (2009)

Additional deterministic simulation of high-end (low-probability high-impact) sea-level rise scenario. (Not included in GSA)

Splinter et al., (2014)
Case of study

Input probability distributions

<table>
<thead>
<tr>
<th>Sea-Level Rise</th>
<th>Depth of Closure</th>
<th>Free Model Parameters (Example ShoreFor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) RCP 4.5</td>
<td>(b) RCP 8.5</td>
<td>(d) ShoreFor parameters $k_s^+, \Phi$</td>
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<td><strong>Time-varying Gaussian distributions</strong></td>
<td><strong>Gaussian distributions</strong> Based on Hallermeier (1978) over sliding window of wave projections</td>
<td><strong>Empirical joined distribution</strong> Based on multivariate kernel density function</td>
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</tbody>
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- Median
- Likely range
- 0.01th - 99.9th percentile
- High-End
- Median
- Likely range
- 0.01th - 99.9th percentile
- Probability density [ ]
- Depth of Closure [m]

Based on SROCC projections and regional fingerprints (Thiéblemont et al., 2019)
The results obtained with the two different modelling approaches (ShoreFor and Yates) show similar seasonal and interannual shoreline cycles, although with different amplitudes and variances.
Uncertainties in shoreline projections are initially driven by uncertainties in model free parameters, with the effects of SLR uncertainties only emerging in the second half of the 21st century…
...However, the time evolution of relative effects of SLR and model parameters uncertainties on shoreline projections is related to the forcing wave climate variability.

It is important to account for uncertainties related to the temporal distribution of wave energy, and therefore the need of ensembles of synthetic wave time series that account for the inherent variability of the wave climate is emphasized.
Acknowledgements

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References:


