Assessing a probabilistic model for guiding storm surge barrier maintenance

Sunke Trace-Kleeberg, Krijn Saman, Robert Vos, Elja Huibregtse, Ivan D. Haigh, Marc Walraven, Annette Zijderveld and Susan Gourvenec

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University of Southampton | Rijkswaterstaat Ministry of Infrastructure and Water Management | I-STORM

This work was supported by the Natural Environmental Research Council [grant number NE/S007210/1]

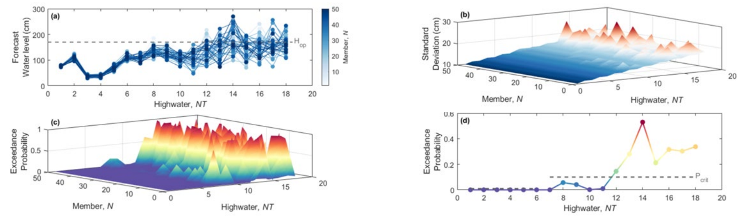
1 Storm Surge Barriers

50+ Storm surge barriers in operation worldwide

- Protect low-lying communities against **coastal flooding**
- Rely on maintenance to keep them **functioning** to the end of their design life
- Consist of **movable gates** that can be closed **temporarily**
- Can only be maintained during "**weather windows**" when conditions are safe
- Require **specialist expertise** to manage, maintain and operate
- Under pressure to complete maintenance due to **ageing** and **sea-level rise**

2 Probabilistic Model *4SVK*

Used at the **Maeslant Barrier**, Netherlands. **Four** main **calculation** steps:



(a) Ensemble forecast high water level, horizontal line indicates threshold, H_{op}
(b) Standard deviation, for each member (n=1...N) at every time step (it = 1...NT)
(c) Exceedance probability of H_{op} for each ensemble member at every time step
(d) Average cumulative exceedance probability (P_{cum}), horizontal lines indicate critical probability (P_{crit}). When $P_{cum} \leq P_{crit}$ safety criterion is met, while $P_{cum} > P_{crit}$ the safety criterion is not met.

3 Evaluating Model Performance

Binary classification is used to evaluate the model performance. This results in four possible outcomes:

Reality		Model Outcome: Safety Criterion **Met**	Model Outcome: Safety Criterion **Not Met**
Reality	Water level is **lower than** threshold	**Correct** True Negative	**False Alarm** False Positive *(Waste of time)*
Reality	Water level is **greater than or equal to** threshold	**Miss** False Negative *(Increased risk)*	**Hit** True Positive

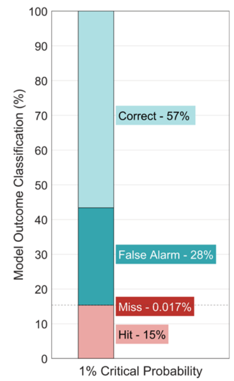
The intention is to limit **False Alarms** and **Misses**

4 Model Baseline

Critical probability: **1%**
Water level threshold: **170cm**

Ensemble forecasts of water level at Hoek van Holland between January 2008 - December 2023 are used to run the probabilistic model in hindcast

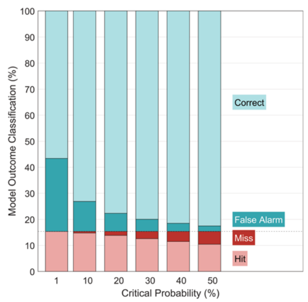
Model performance is determined by comparing model outcome to observed water levels from tide gauge:



5 Sensitivity Tests

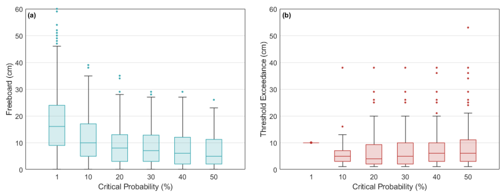
Values for **critical probability** and **water level threshold** are adjusted to test the sensitivity of the probabilistic model

Six thresholds are tested from 1% - 50% and 110cm - 210cm



6 Incorrect Model Outcomes

Annual and monthly percentage occurrence of **False Alarms** and **Misses**. Calculating the difference between observed and forecast water levels. Analysing the values for **freeboard** and **threshold exceedances**



Key Findings

- First **probabilistic model** using **ensemble forecasts** to aid **decision making** on when storm surge barrier maintenance can start
- **Hindcast evaluation** shows **baseline model** performs well albeit conservatively. Model is a **useful tool** to guide decision-making
- Adjusting **critical probability** and **water level threshold** shifts the **balance** between incorrect model outcomes

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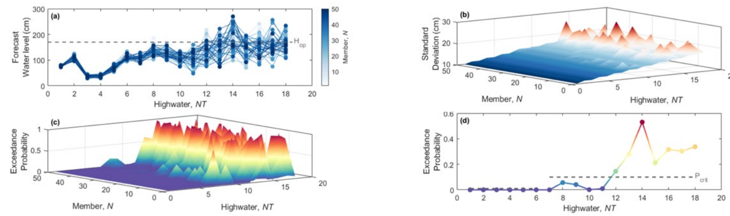

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3 Evaluating Model Performance

Binary classification is used to evaluate the model performance. This results in four possible outcomes:

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Water level is lower than threshold	Correct	False Alarm
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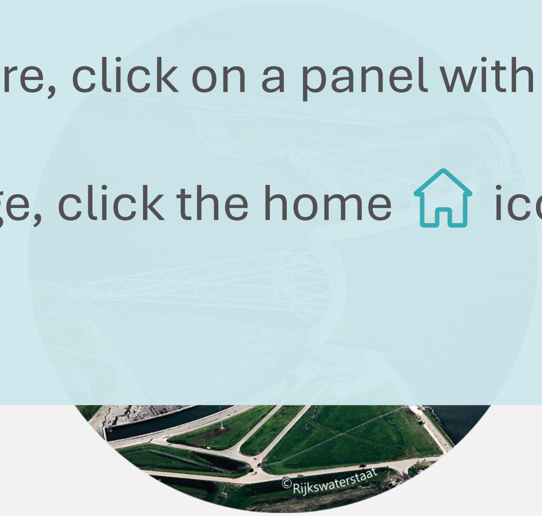

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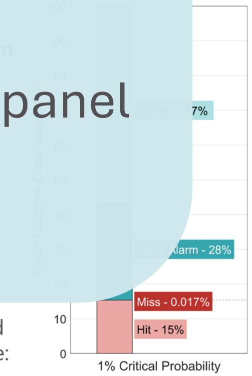

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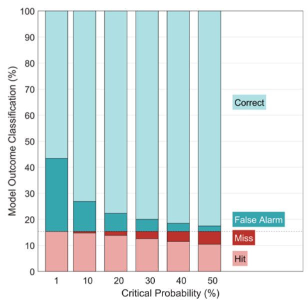

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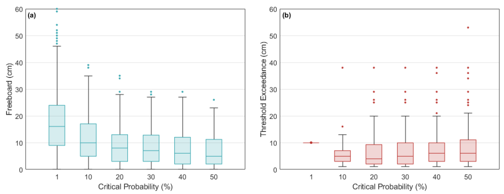

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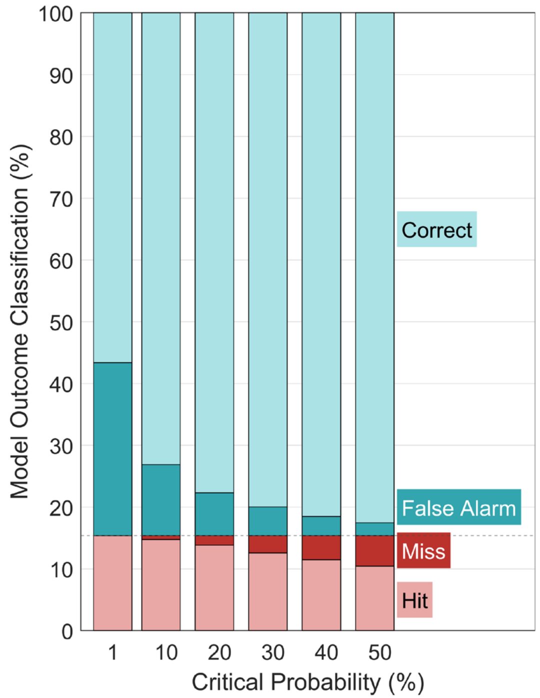
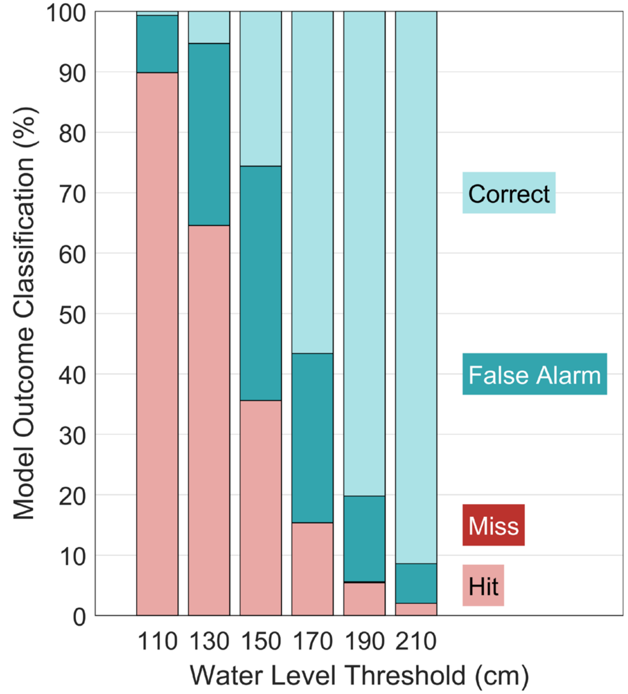
Sensitivity Tests

Impact of altering **critical probability** and **water level threshold** on model performance is assessed





As **critical probability** increases the number of **False Alarms** reduce although this coincides with an increase in the **Miss** outcomes

As **water level threshold** changes the proportion of **False Alarms** reduce. There are more outcomes that allow maintenance work at higher thresholds

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Incorrect Model Outcomes

Critical Probability

Water Level

Click the boxes to see more figures

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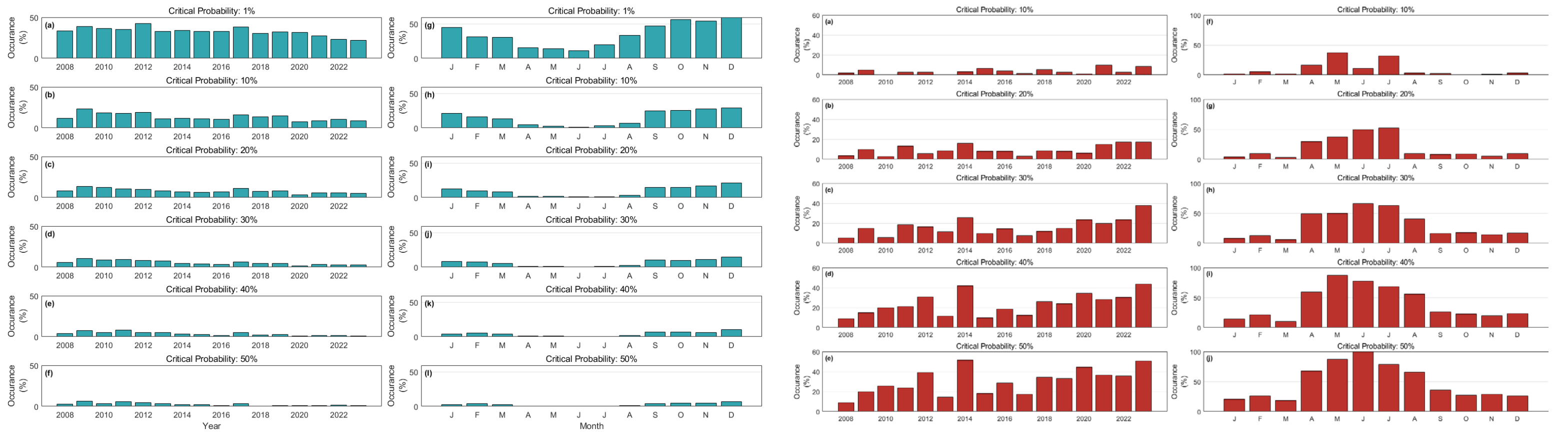
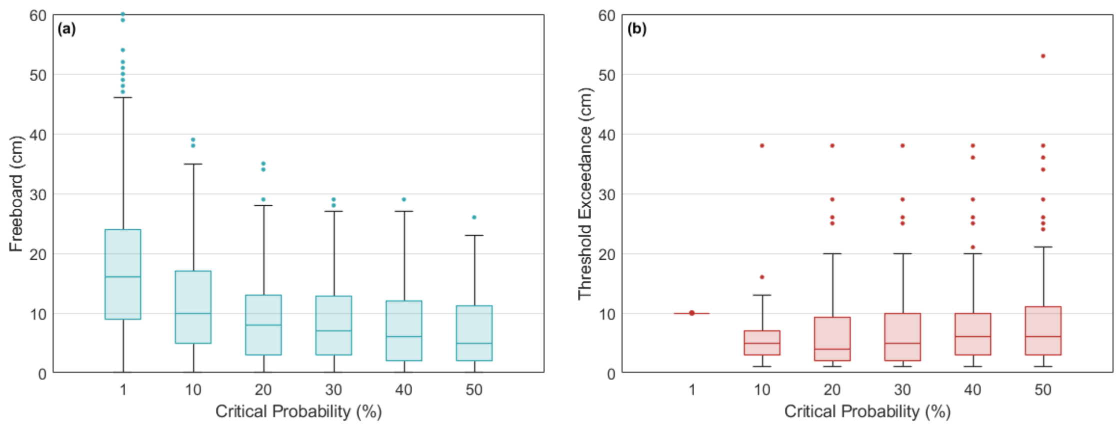
Incorrect Model Outcomes

Annual and monthly percentage occurrence of **False Alarm** and **Miss** outcomes



Difference between forecast and observed water level of incorrect model outcomes



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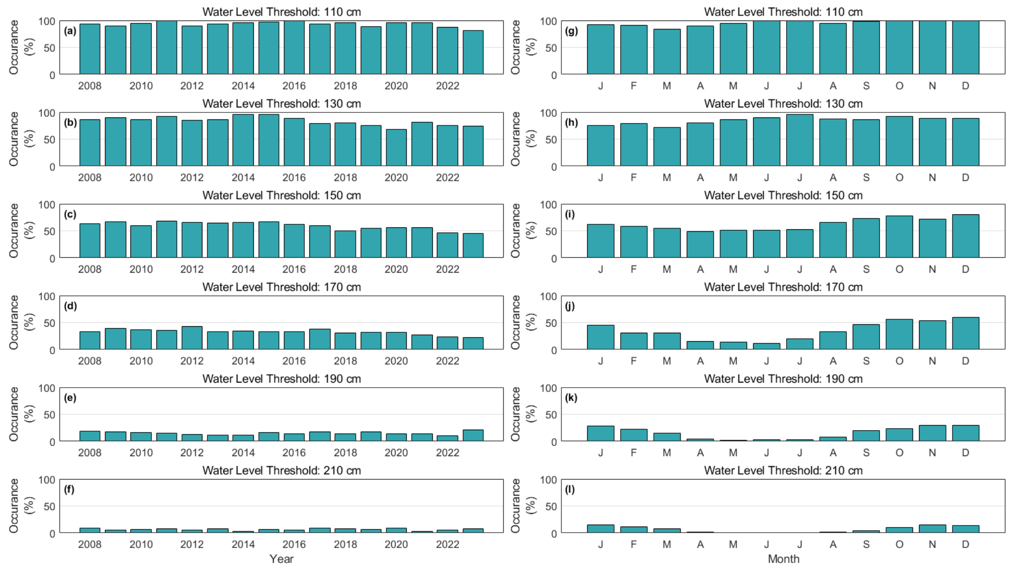
Incorrect Model Outcomes

Annual and monthly percentage occurrence of **False Alarm** outcomes



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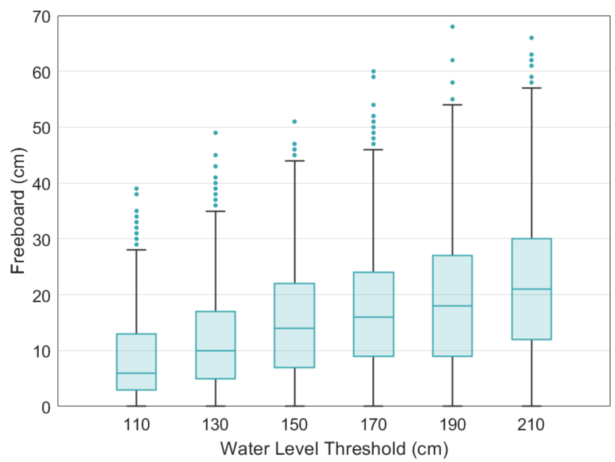

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