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Enabling Delta Life

Dutch approach to coastal flood hazard

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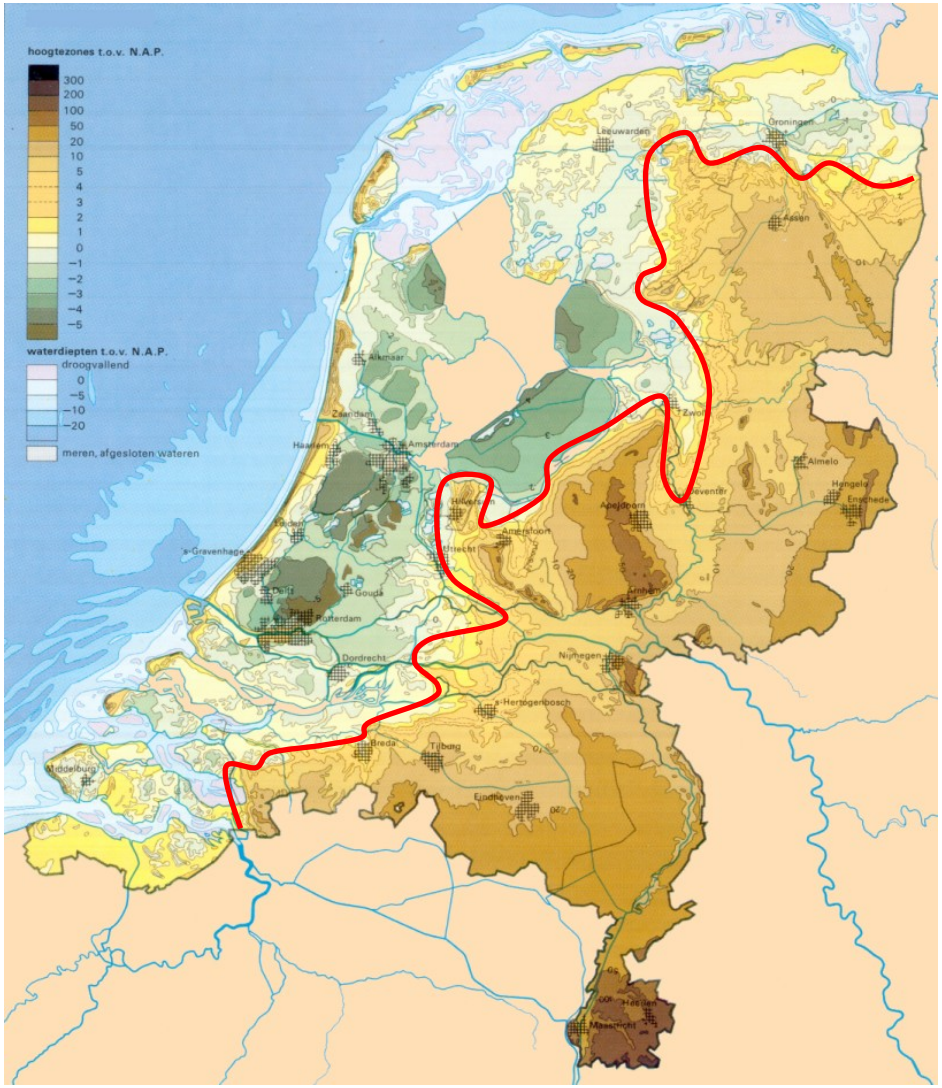
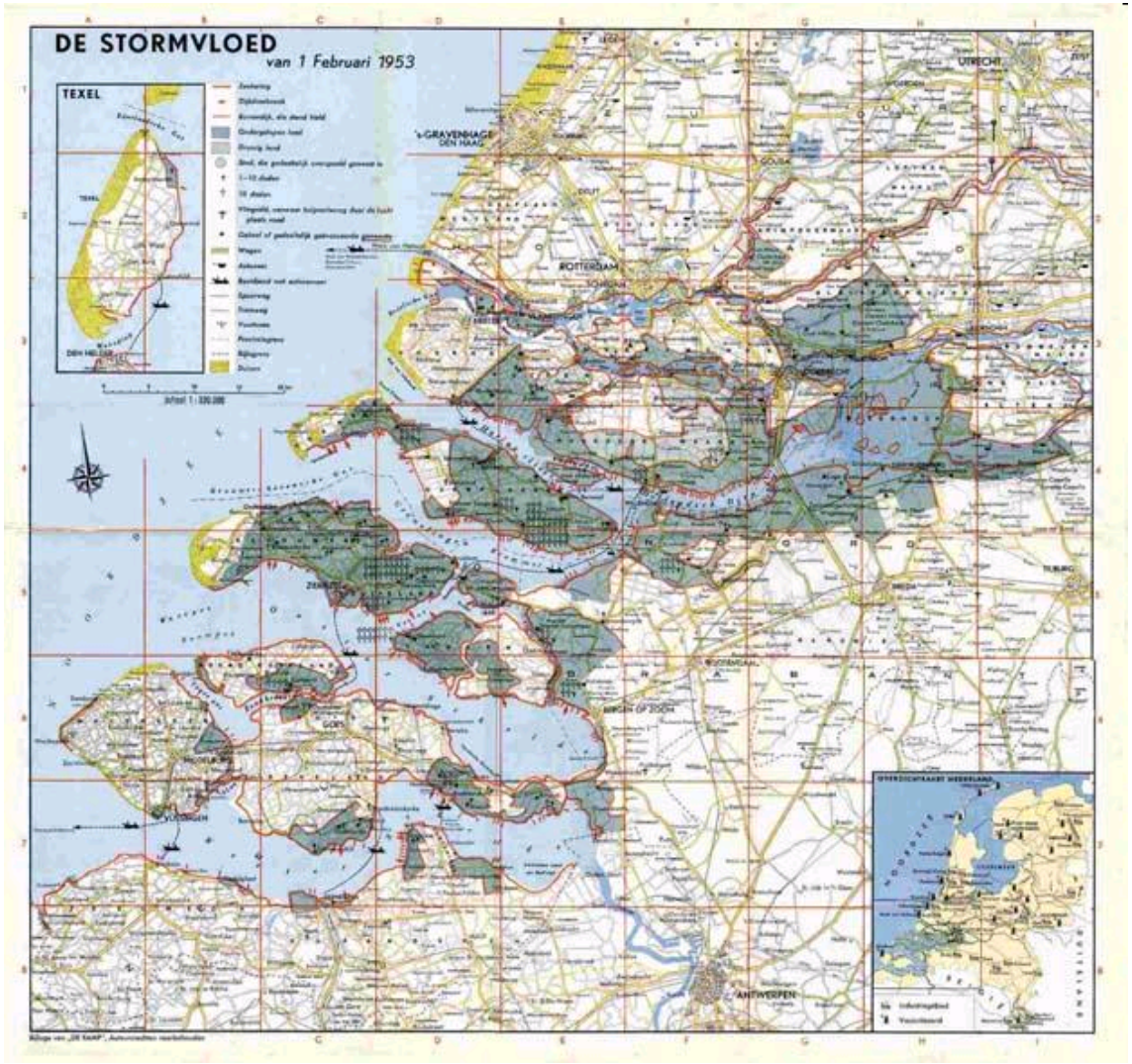
January 28, 2013, NRC Workshop on PFHA, Rockville MD

The Netherlands



Flood of Feb 1st 1953



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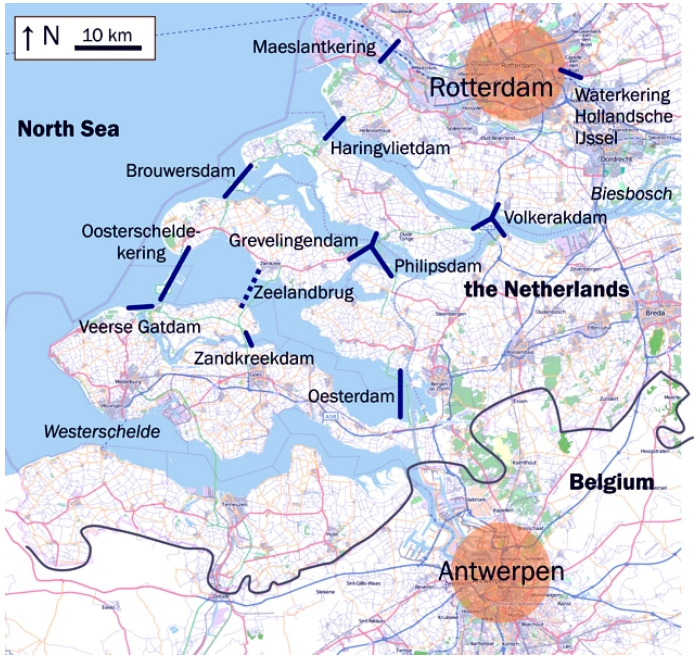
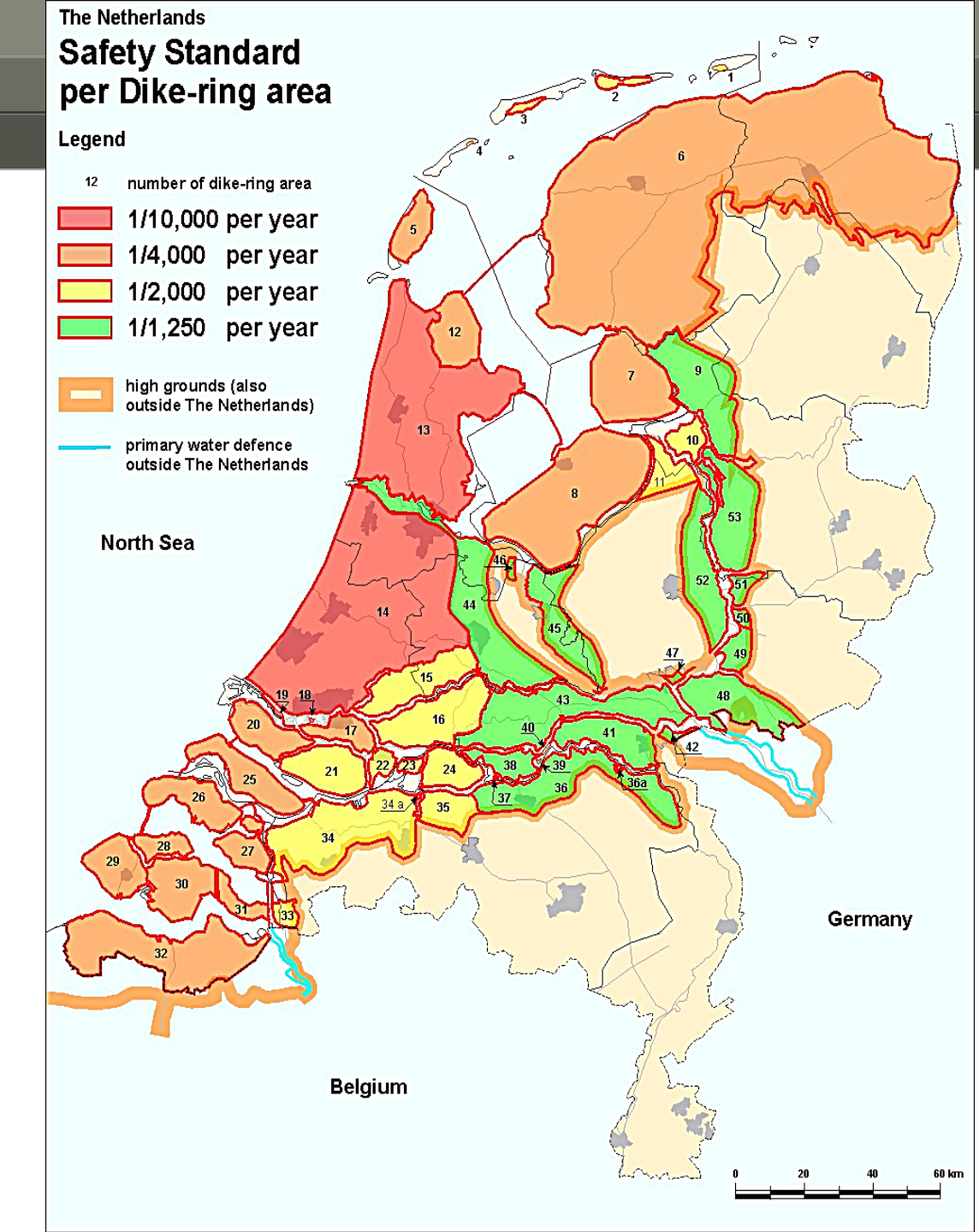
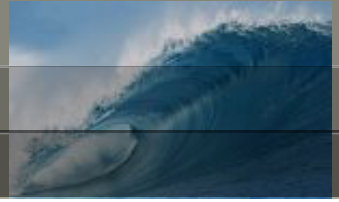
Response to the 1953 Flood



- Improvement of flood protection
- Closing of estuaries with dams and storm surge barriers
- Formal safety standards in terms of probabilities





Coastal defenses:

1/4000 - 1/10.000 per year

Estuaries:

1/2000 per year

River levees:

1/1250 per year

Water Act (1990): periodic safety assessment

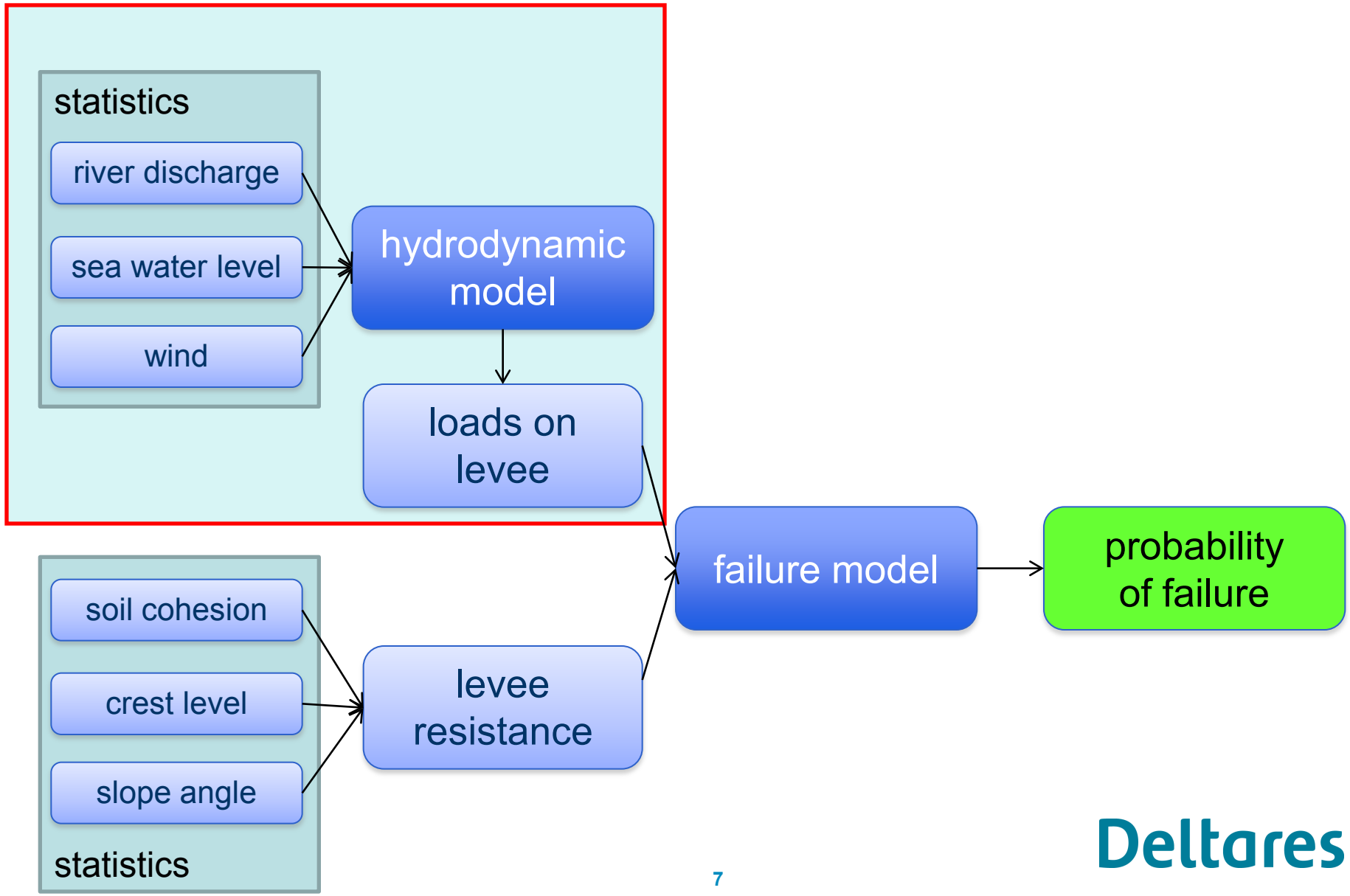
- Done every 5 years
- Performed by Water boards
- Tools and methods prescribed by Ministry of Infrastructure
- Central role for probabilistic methods

Levees

Dunes

Hydraulic structures

Safety assessment – probabilistic framework



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Example: Coastal sea defense

Failure mechanism: wave overtopping

Load = water level and wave conditions
Resistance = height and profile of the levee

Aim: determine the probability of a
critical overtopping discharge of >1 l/m/s

Required input:

- Water level statistics
- Wind statistics (direction and speed)
- Wave model for transformation of wind to nearshore waves

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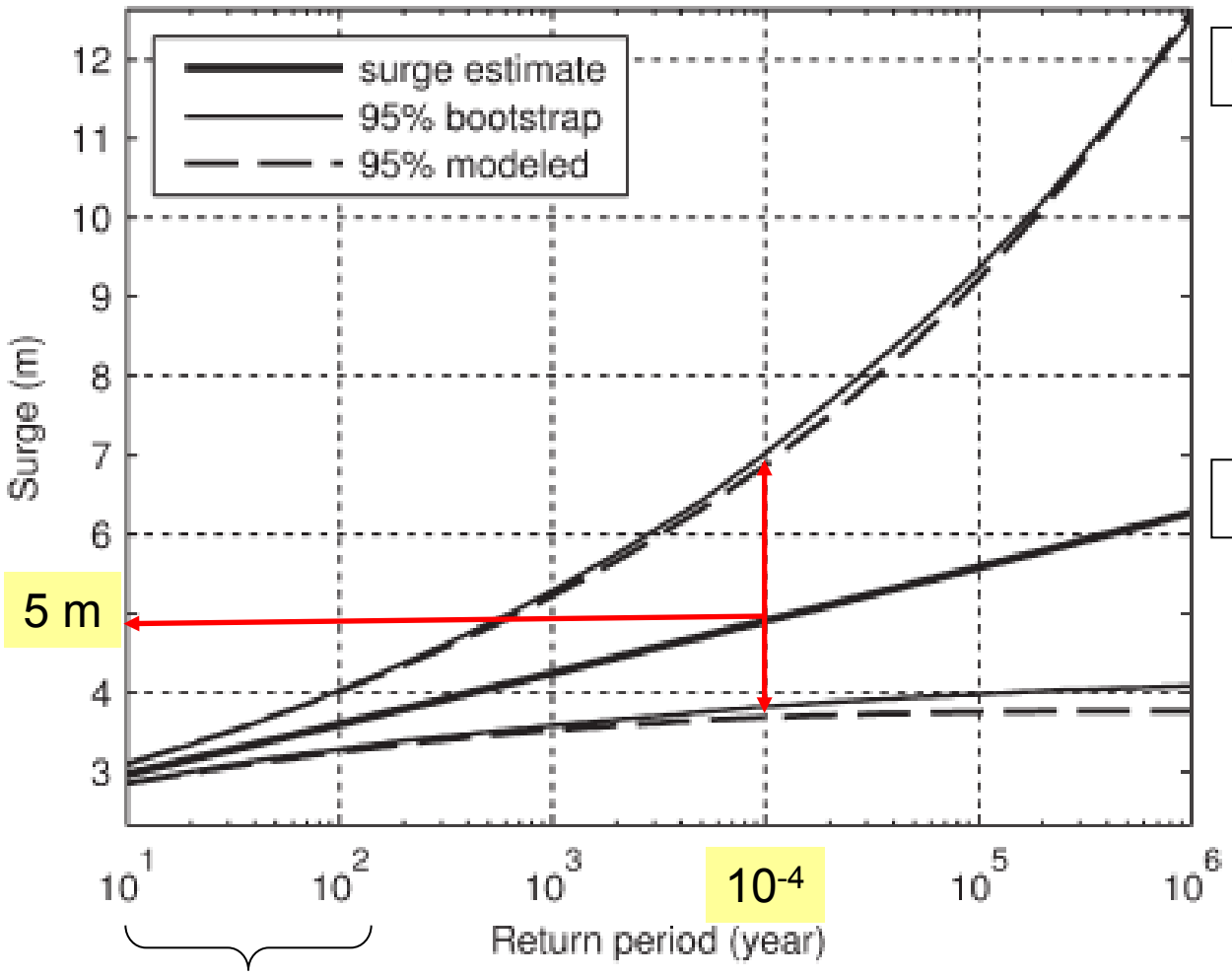
Water level statistics at gauging stations



95% uncertainty

GPD on POT

5 m

Range of Observations

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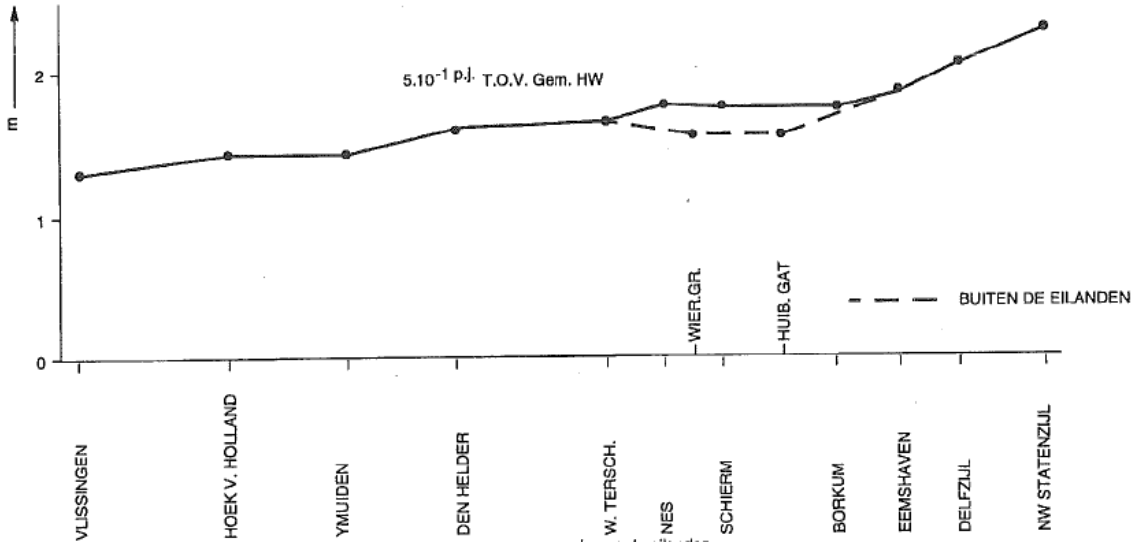
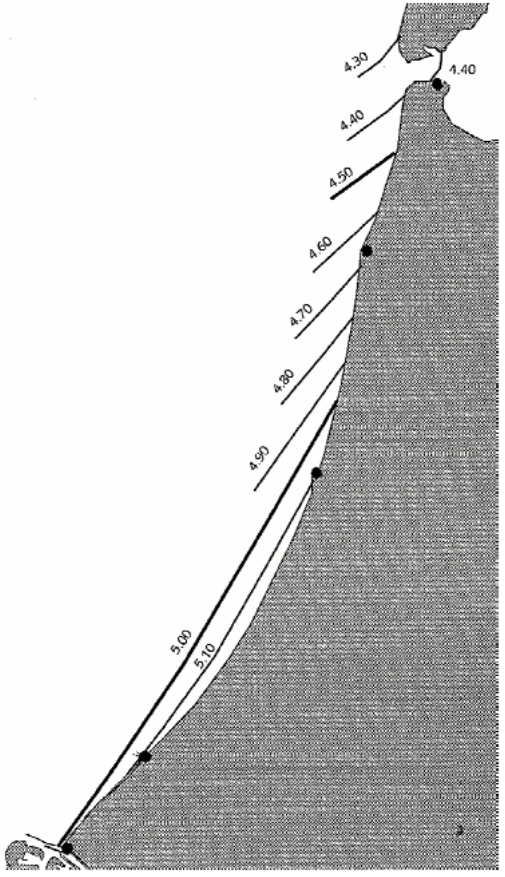
‘Modified’ Regional Frequency Analysis

Variation to RFA for a non-homogeneous region:

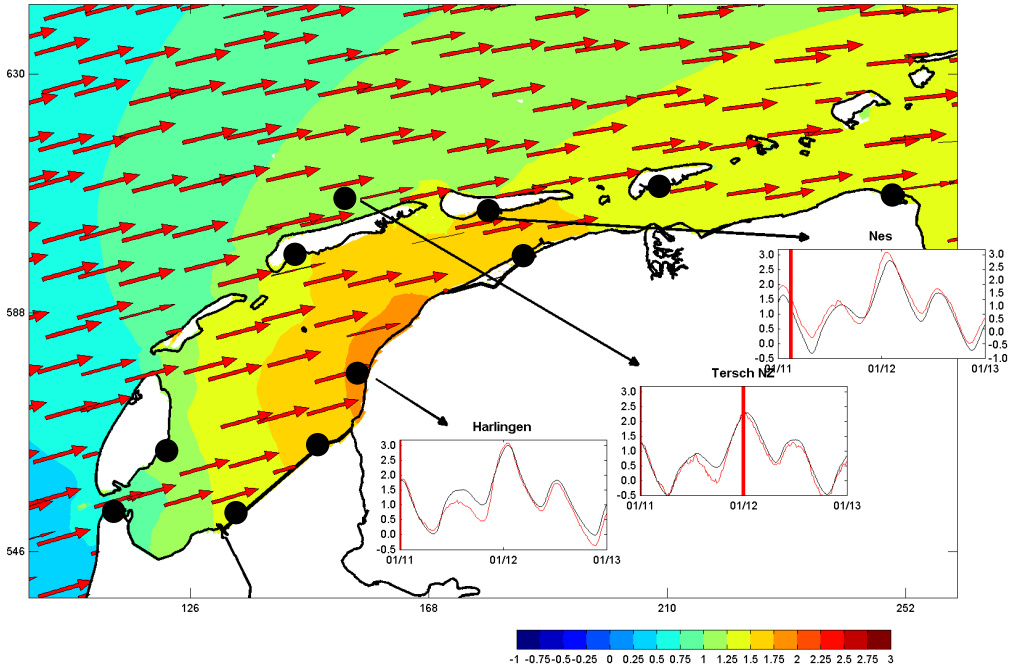
GPD shape parameter may vary, but follow a coherent spatial pattern

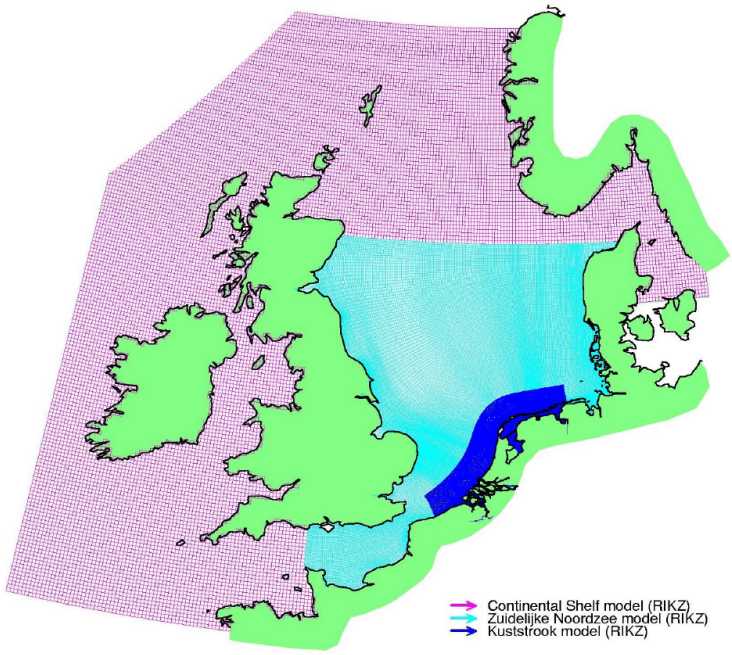
Constraints on shape parameter, combine with hydrodynamic modeling and expert judgment





Hydrodynamic modeling





Use Delft3D model simulations of ‘superstorms’ to:

- Improve the consistency between stations
- Get surge levels at other locations
- Verify the feasibility of extreme surge levels

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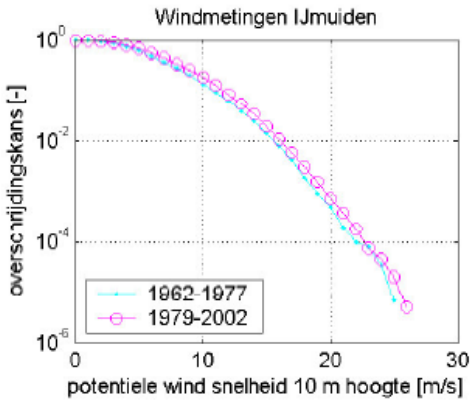
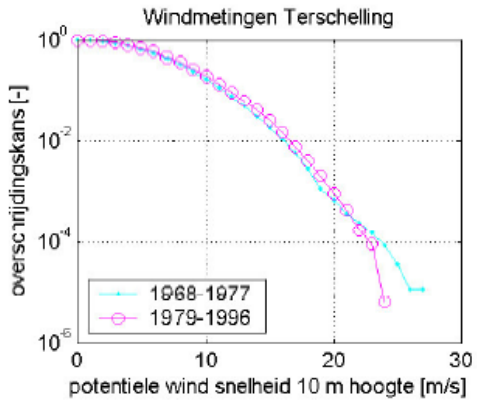
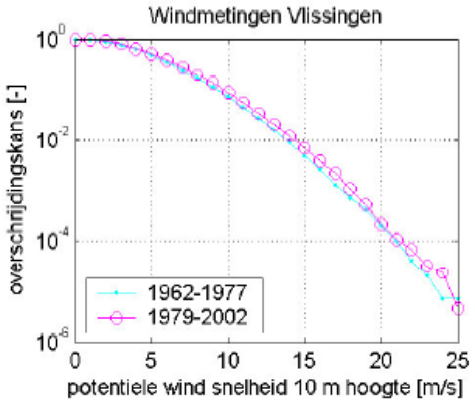
Wind statistics

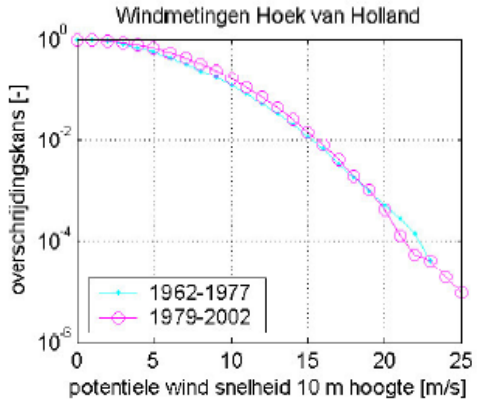
Wind statistics:

- Potential wind speed at 10m
- Conditional on wind direction (12 sectors)
- GPD on POT
- PW-Moments
- ‘Modified’ RFA



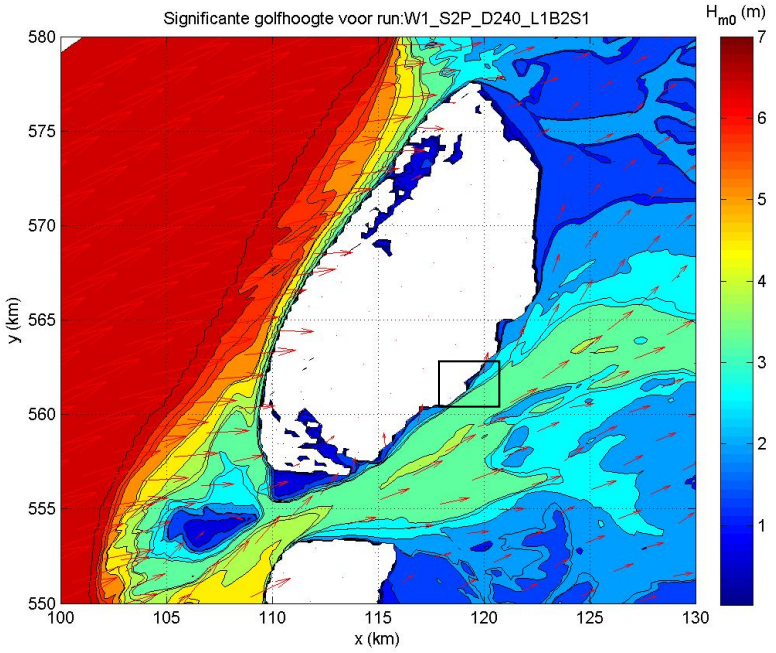


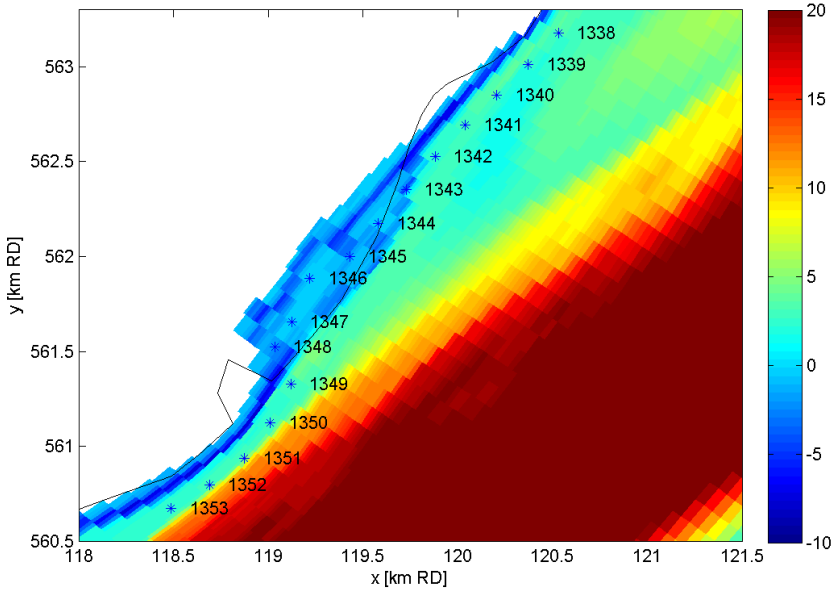




Nearshore wave conditions

- SWAN (Simulation WAves Nearshore)
  Delft University model for wave generation and propagation
- Translate offshore wind to nearshore wave conditions
  Significant wave height H_s and spectral wave period $T_{m-1,0}$
- Use nested grids from full North Sea down to resolution of 25 m.





http://www.swan.tudelft.nl

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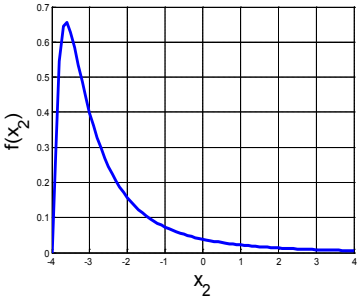
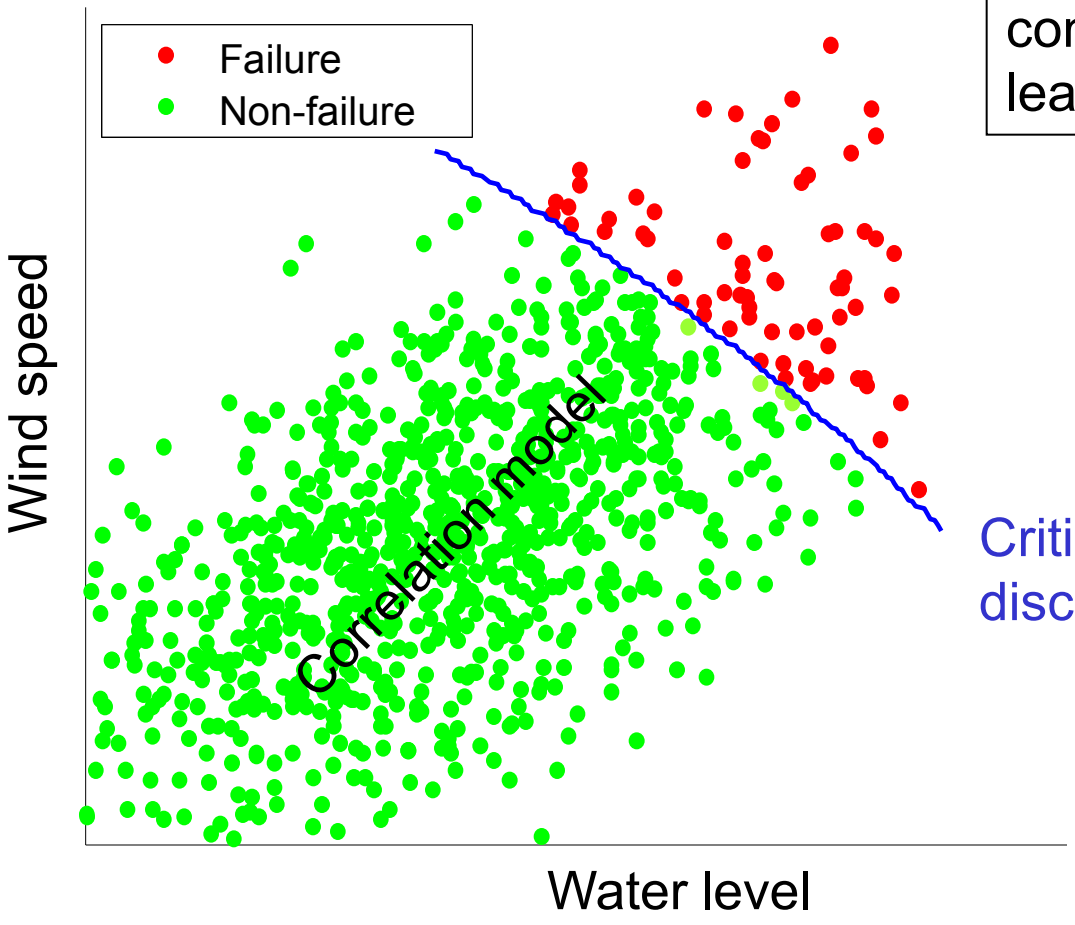
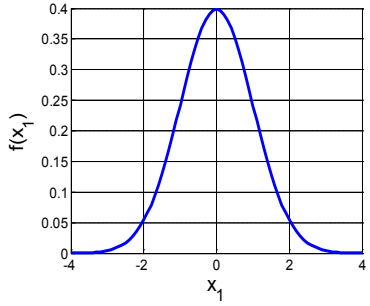
Calculate failure probability



Integrate over all combinations that lead to failure



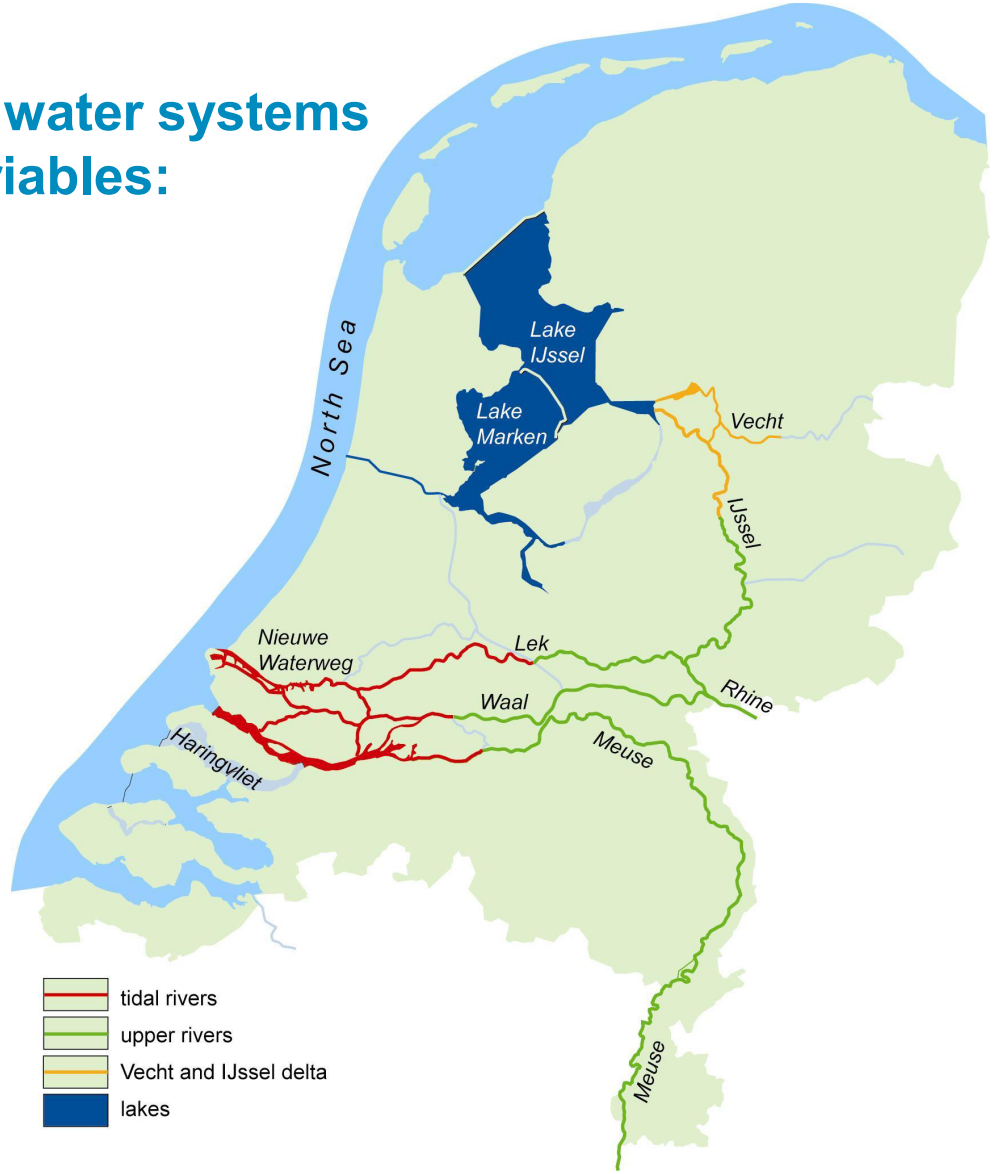
Critical overtopping discharge



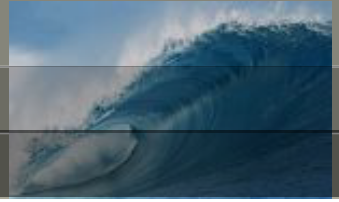
Probabilistic models – Hydra family

Different models for different water systems and associated forcing variables:

- Coast
- River
- Lake
- Tidal river into sea
- River into lake



Dealing with uncertainty (1)



Aleatory uncertainty: natural variability

Epistemic uncertainty: model and statistical uncertainty

First generation of Hydra models (1990's):

For the safety assessment:

- Use best estimates of hydraulic load
- Disregard epistemic uncertainty

For (re)design of flood protection:

- Apply safety margins for model uncertainties
- And margins for sea level rise and land subsidence.

Any newly built structure will pass the safety assessment

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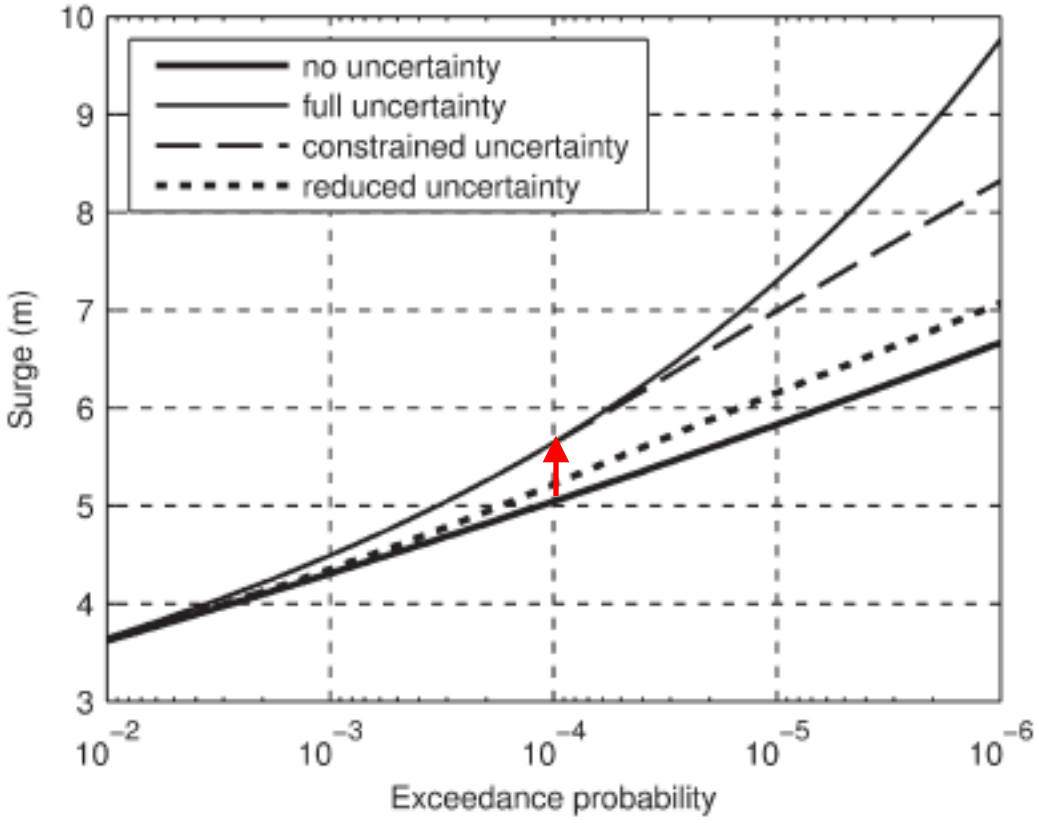
Dealing with uncertainty (2)

New generation of Hydra models:

Epistemic uncertainties as random variables in the probabilistic model

Example: uncertainty in water level frequency curve



Statistical uncertainty included in the AEP

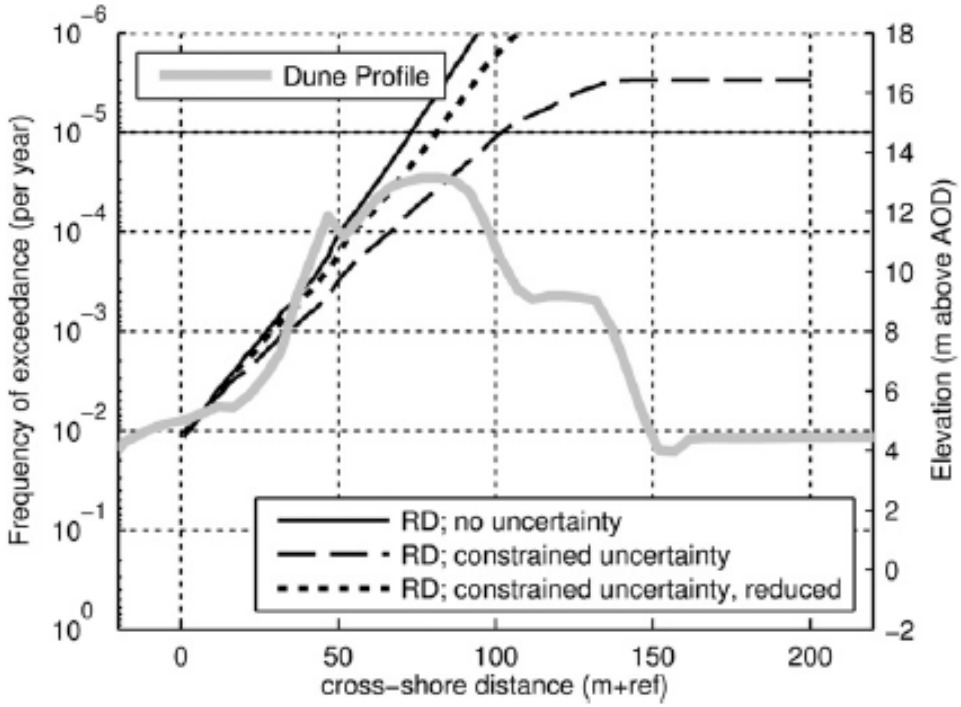
Increase of 10^{-4} AEP surge level of 50 cm

Roscoe and Diermanse, Coastal Engineering 58 (2011) 1023–1033

Effect on failure probability

Dune erosion model

At 10^{-4} level, increase in retreat distance: 10-20m



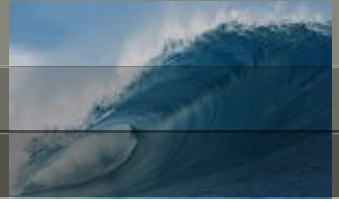
Failure probability increases to $2*10^{-6}$

Dune would still pass the safety assessment

Contribution of statistical uncertainty ~10%

Roscoe and Diermanse, Coastal Engineering 58 (2011) 1023–1033

Summary and conclusions



- Flood risk management based on AEP's of 1/10,000 can be done
- Large uncertainty in extrapolation of frequency curves
- Use (M)RFA and hydrodynamic modeling for spatial coherence and improve general confidence in the frequency curves
- Current safety assessment procedures are based on best estimates of exceedance frequencies of the hydraulic load
- Probabilistic models are being developed that allow for a Bayesian approach. Informative for:
  - Probability of failure according to Bayesian interpretation
  - Contributions of uncertainties to failure probability
  - Relevance for the decision at hand

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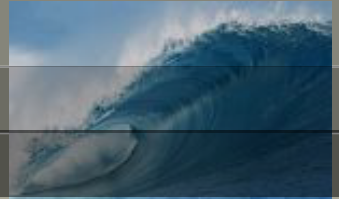
Thanks for your attention



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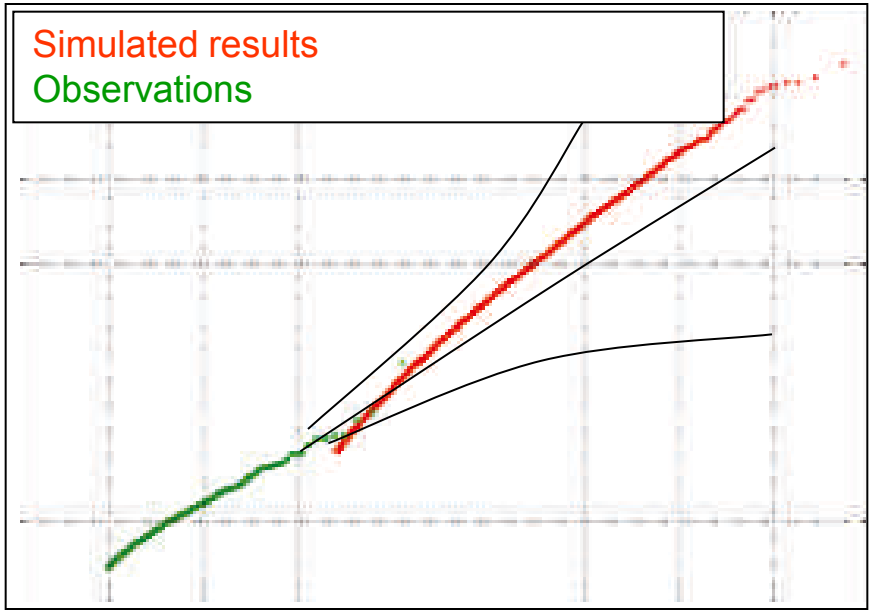
Extra slide: Stochastic storm modeling

Random variables are depression track, speed, size, depth

Probability distributions based on historical storms

Hydrodynamic modeling produces surge levels

Compare results with statistical extrapolation



Work by Mathijs van Ledden (Royal Haskoning, Delft University) Matthijs de Jong (Delft University), Kees den Heijer (Delft University ,Deltares) and Pieter van Gelder (Delft University)

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