Deltares
Enabling Delta Life

Combined storm surge – riverine flood events

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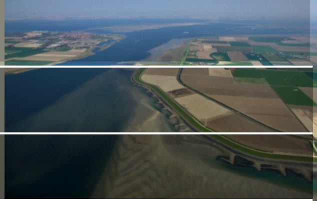
NRC Workshop on PFHA, Rockville MD, January 2013



Outline

- Tidal rivers – combined influence from surge and river
- Challenge for PFHA: need to consider many combinations of surge and river discharge
- Account for correlations
- Example of how this is done for Rotterdam

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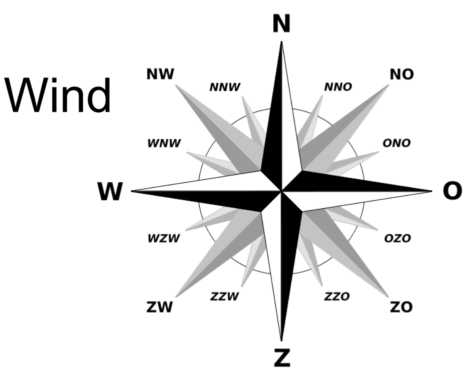
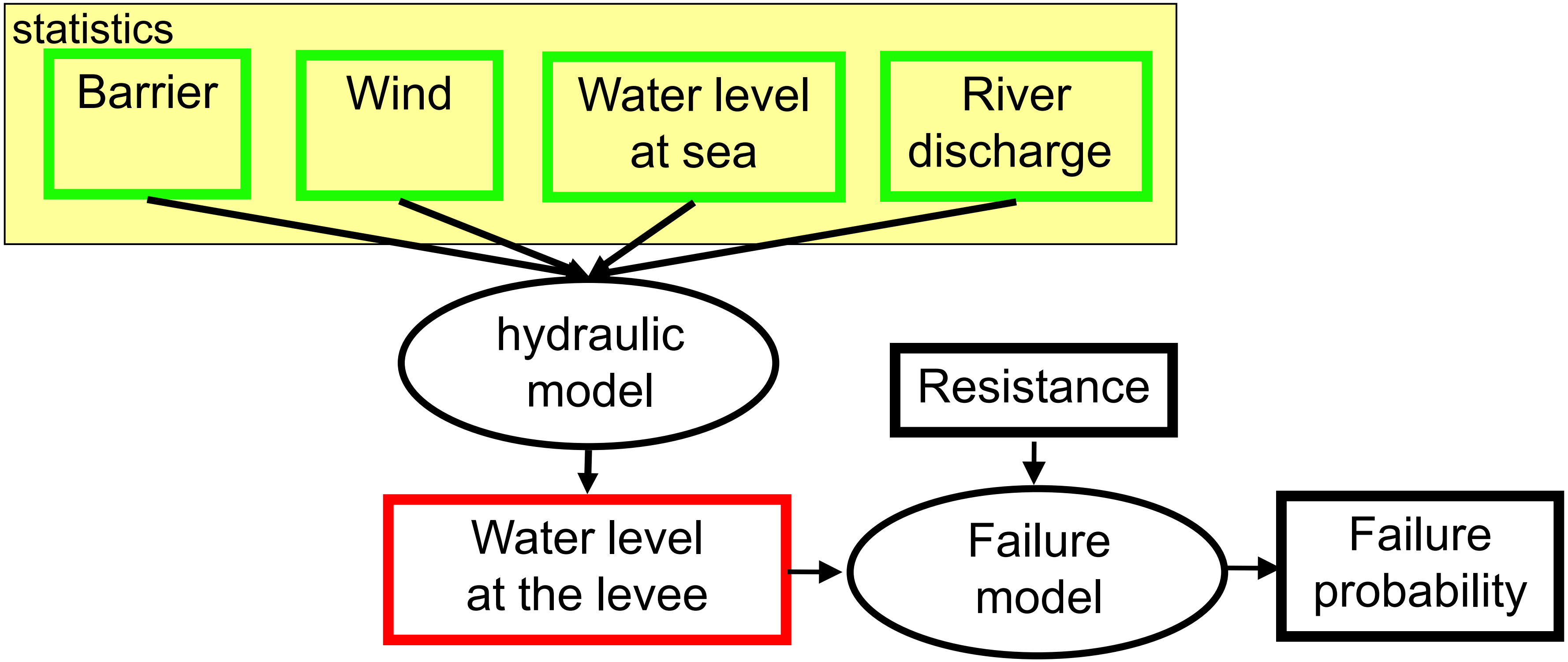
Rhine-Meuse estuary



Probabilistic model



To get the exceedance probability of a water level at the levee

- **Consider all relevant combinations of forcing variables**
- **Calculate the water levels at the levee**
- **Determine their probabilities**
- **Integrate probability over all combinations**

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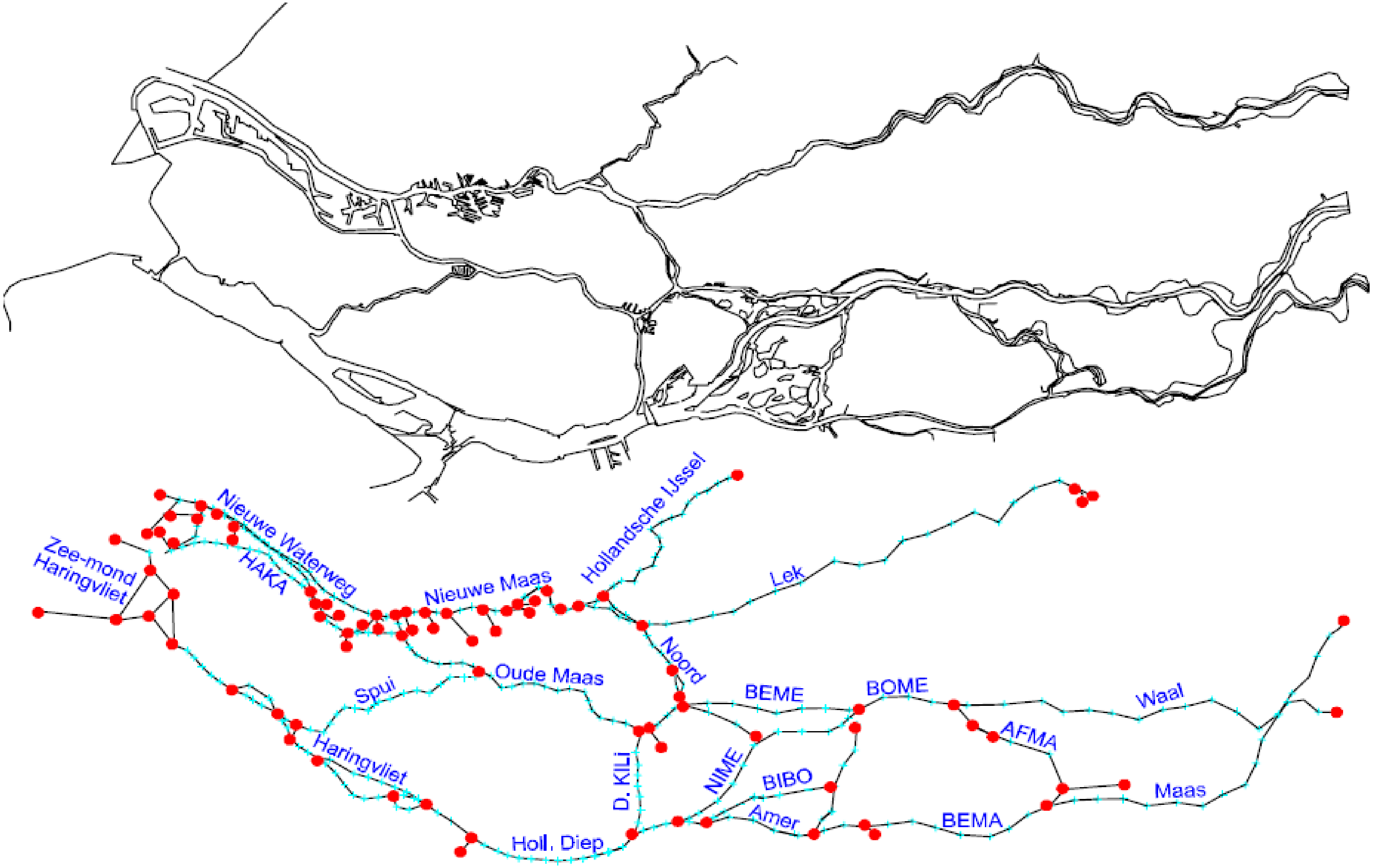
Sobek 1D hydraulic model



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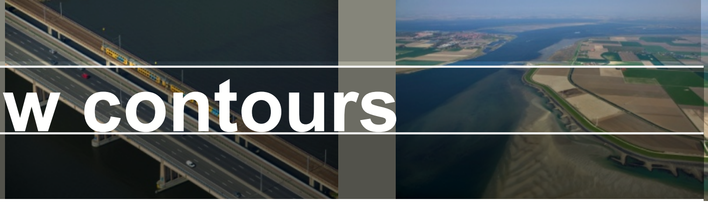
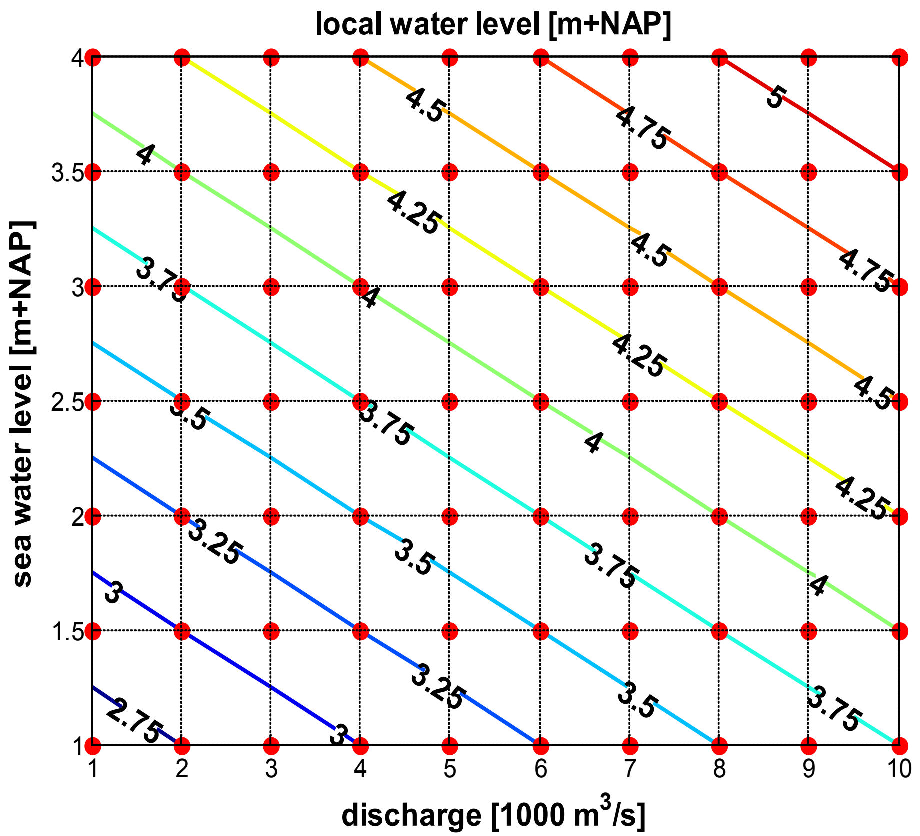
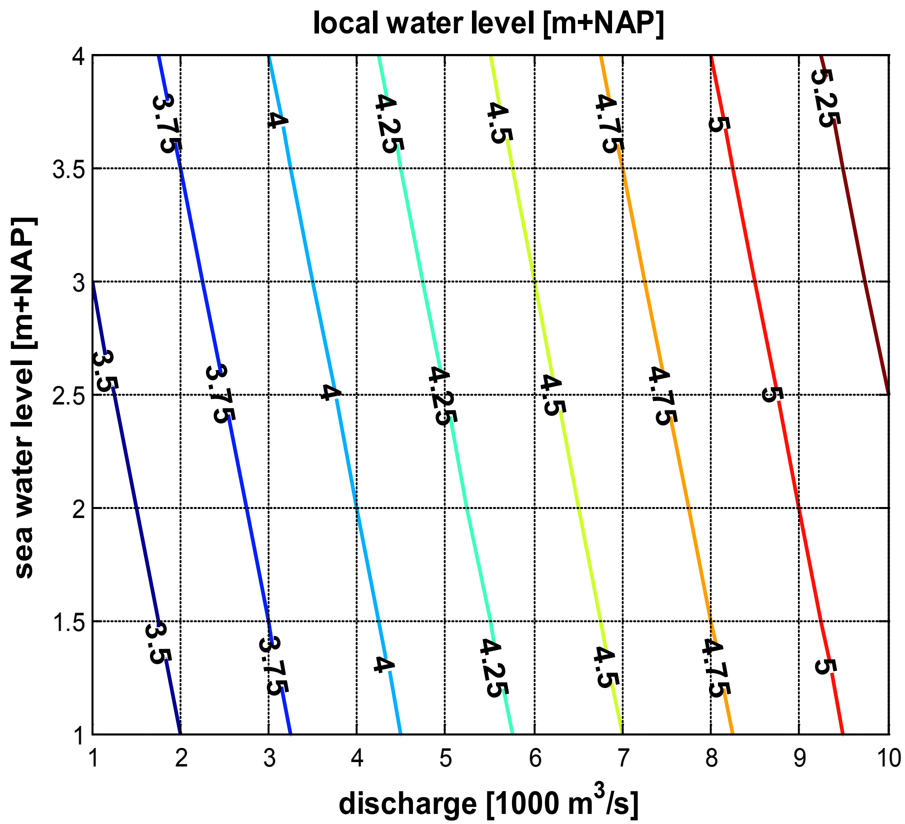
Calculate water levels and draw contours



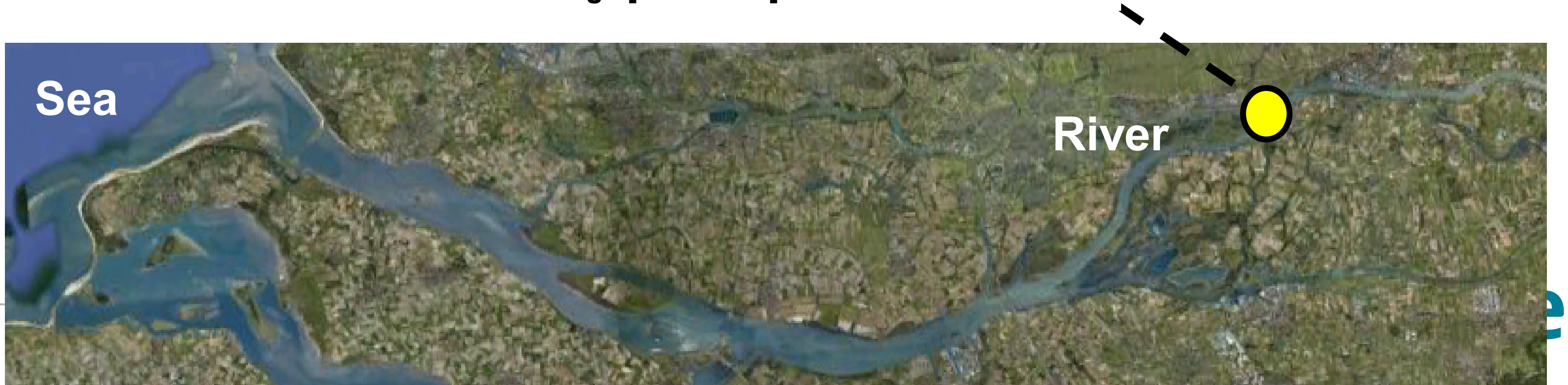


Water levels at location of interest computed by hydraulic model

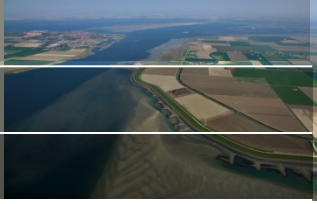
Upstream location

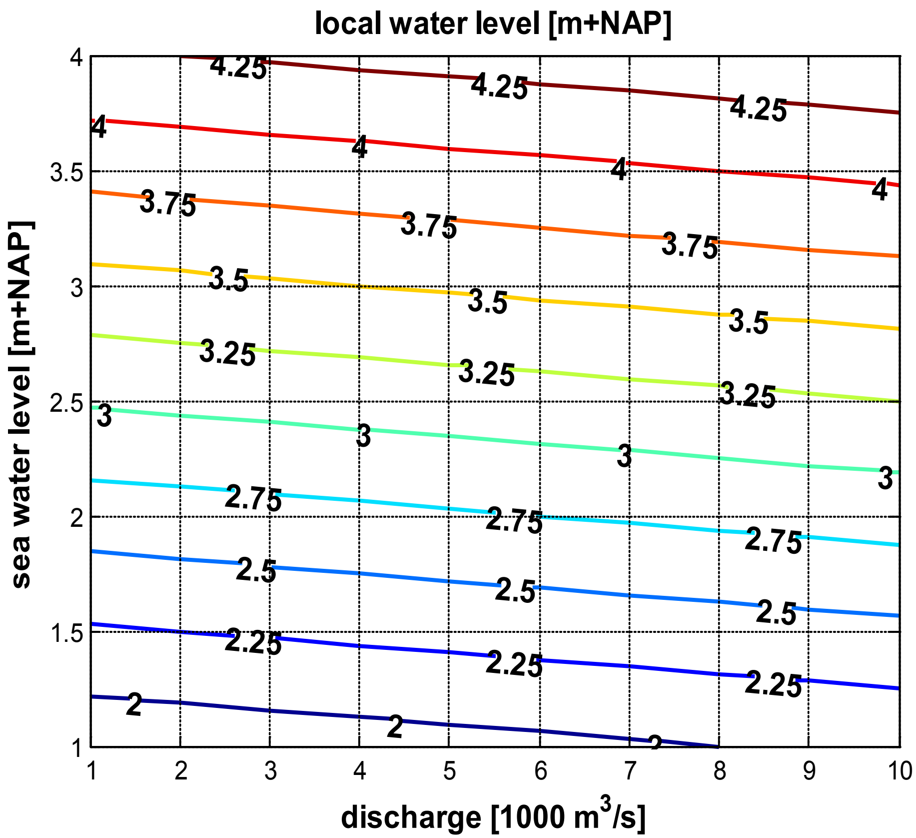


Water levels mainly determined by river discharge



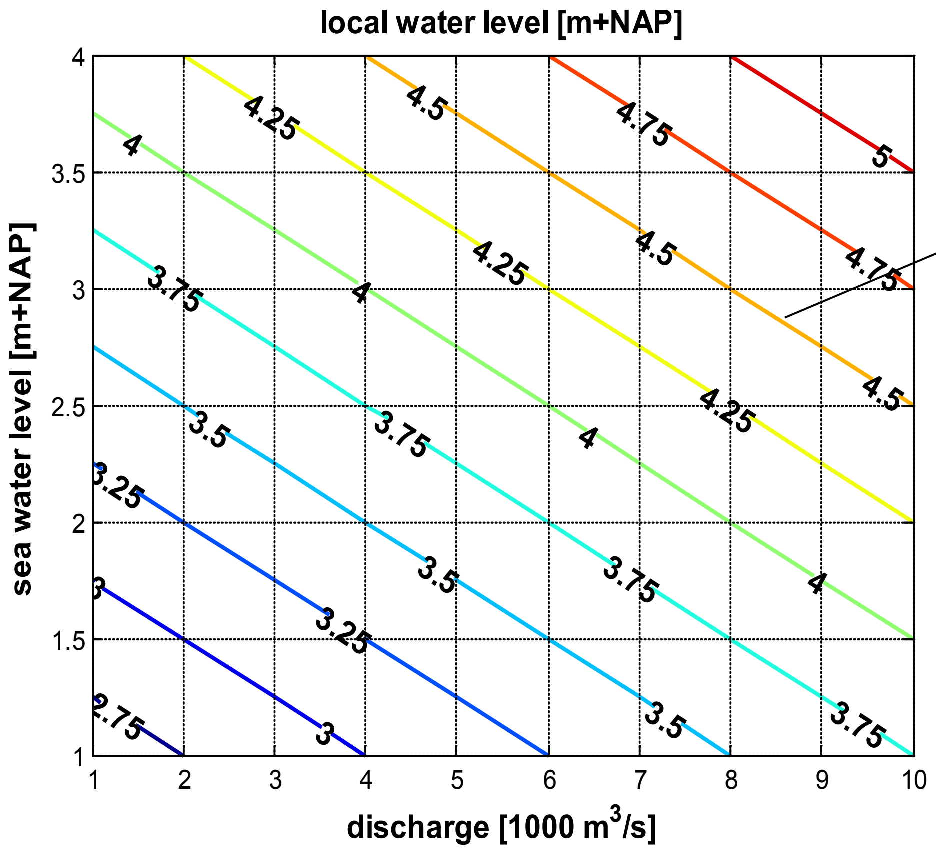
Downstream location





Water level mainly determined by sea water level

Compute exceedance probability



Example: flooding occurs if h>4.5 m+NAP

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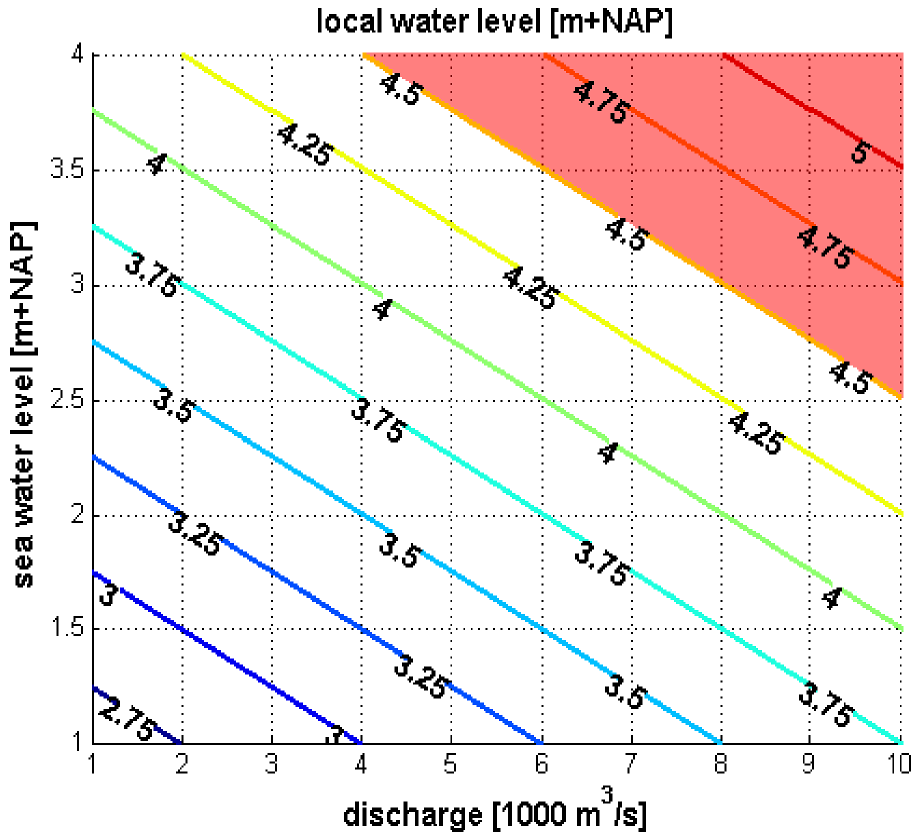
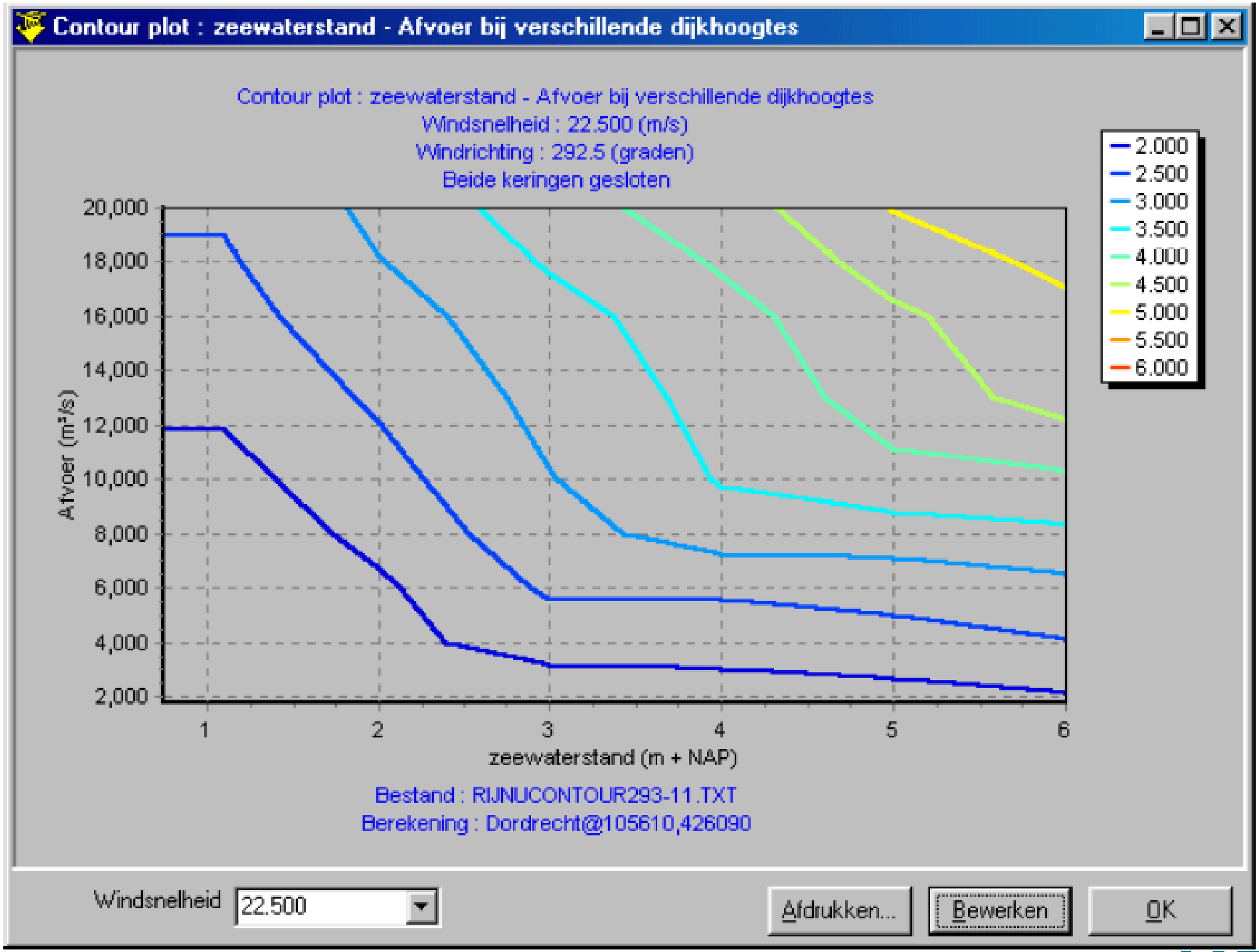
Compute exceedance probability



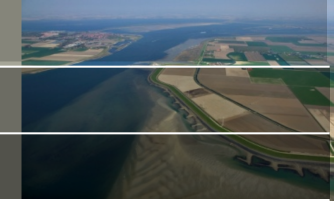
Failure domain

Integrate probability over failure domain

Results Rotterdam – contour plot



Forcing variables for Rotterdam



Variables:

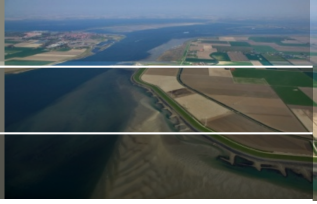
❑ North Sea water level (1,2,3,4,5,6m)	6 values
❑ Rhine and Meuse discharge (2 times 9)	18 values
❑ Wind direction	16 wind sectors
❑ Wind speed	5 values
❑ Open/closed storm surge barrier	2 possibilities

Total number of combinations: 7000

Several weeks on a single PC, some days on a 10 PC cluster

Store in a database. Next, determine their probabilities

Statistics and dependencies



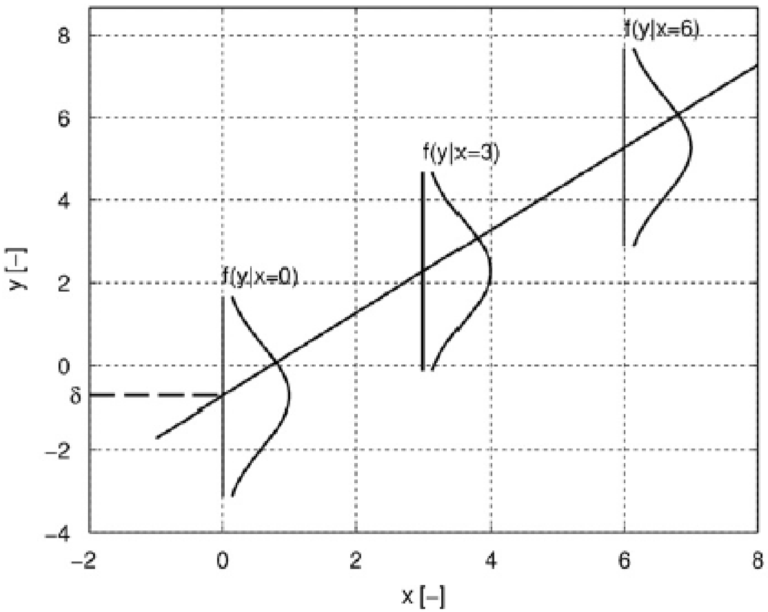
Consider 16 wind sectors:

- ❑ Separate sea water level statistics for each wind sector

  Probabilities of all wind sectors should add up to onmidirectional

- ❑ Separate wind speed statistics for each wind sector

  Correlated with sea water level:



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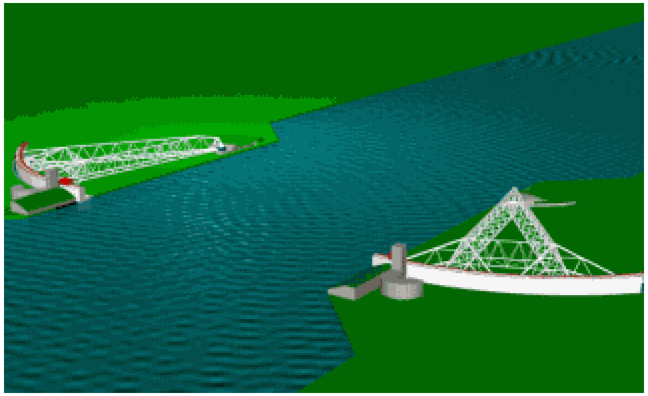
Statistics and dependencies (2)

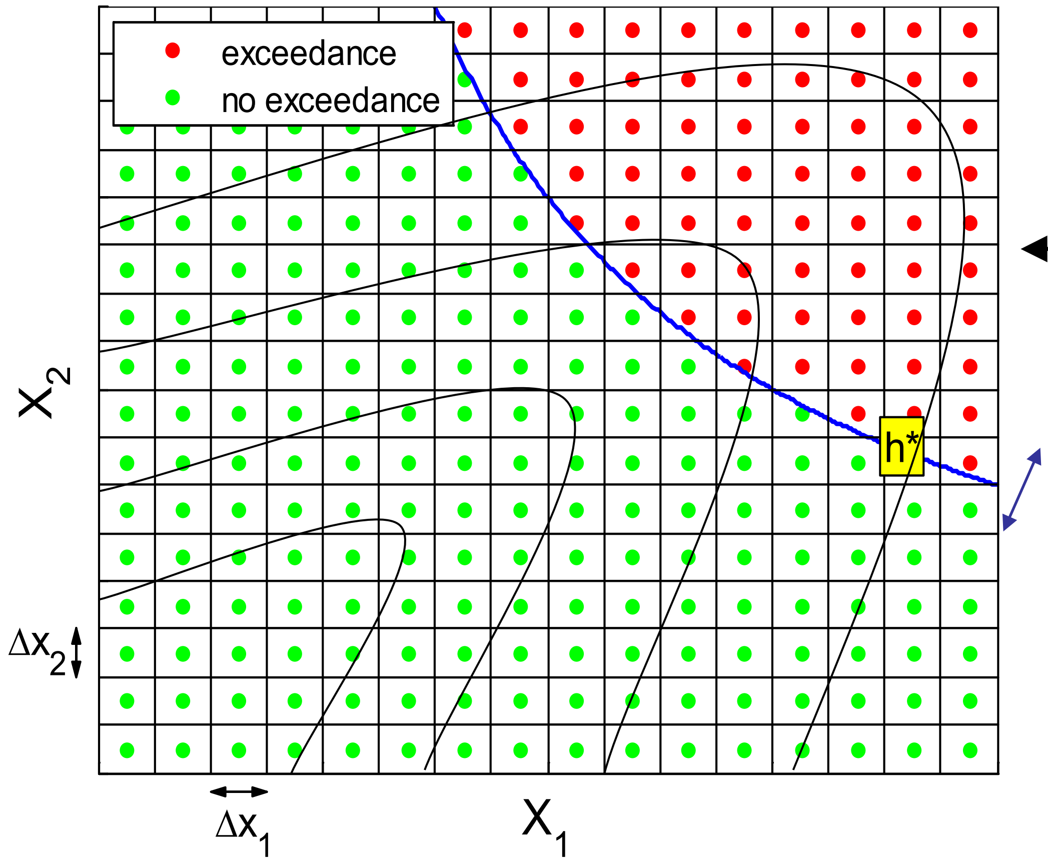


- Open/closed storm surge barrier:
  - Open due to erroneous forecast
  - Additional 1% probability of failure

- Rhine and Meuse discharge
  - mutually dependent
  - independent of other variables

Numerical integration of probability

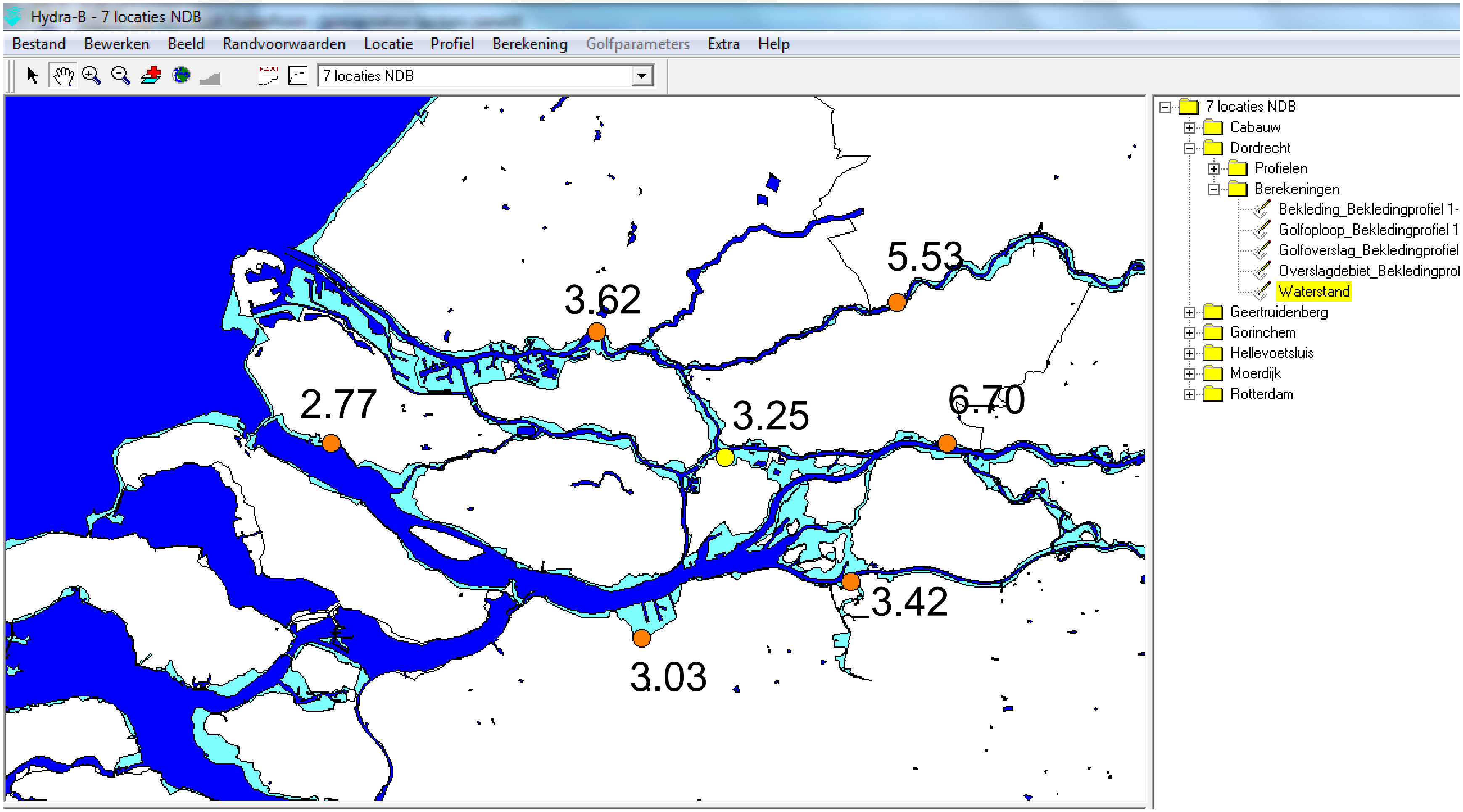
Probability of exceedance of critical water level h*



Failure domain

Vary h* to get the water level for a given probability

Results: 1/10,000 year water levels



Large contribution from combinations of less than extreme surges and discharges and of ‘open barrier’ situations to exceedance probability

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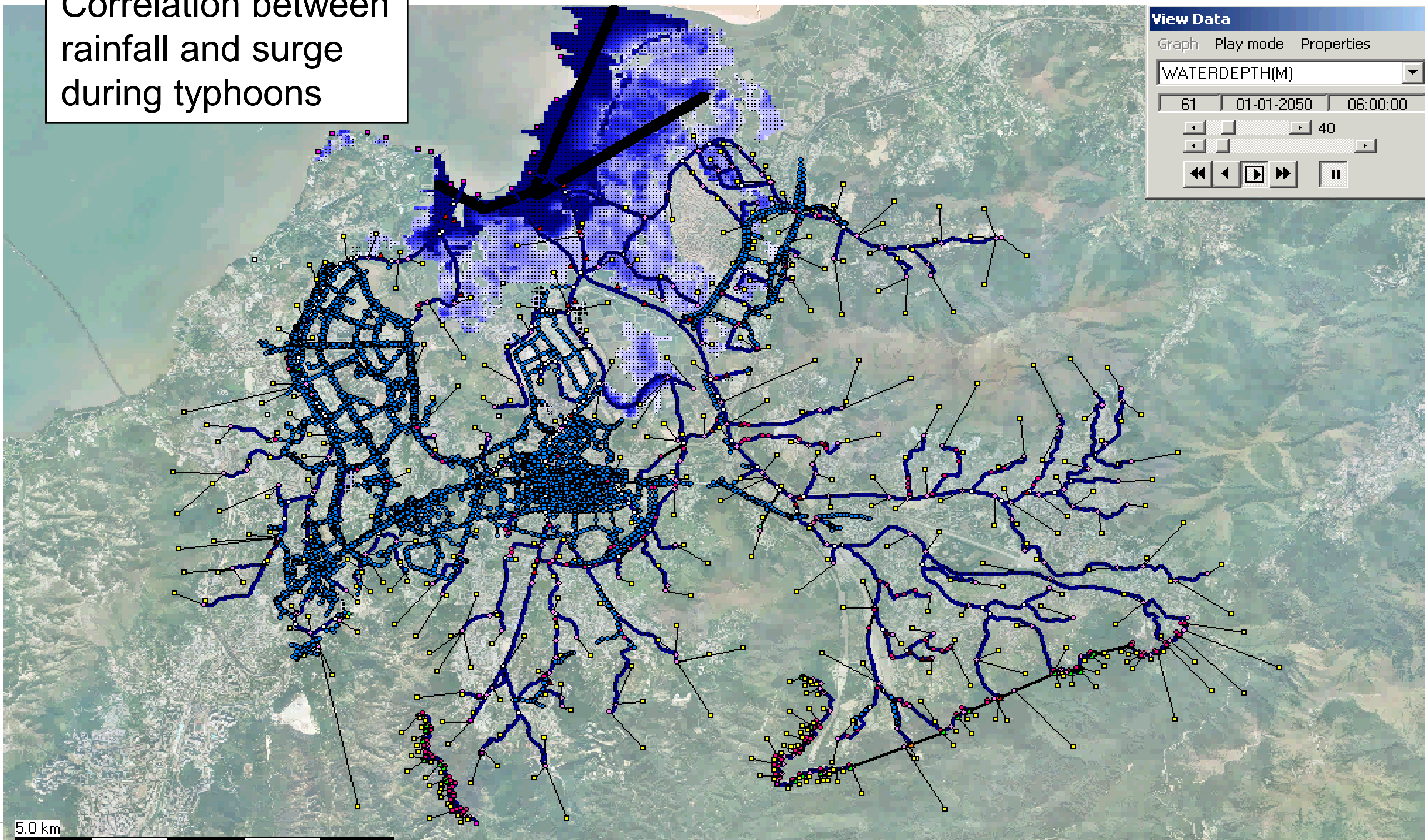
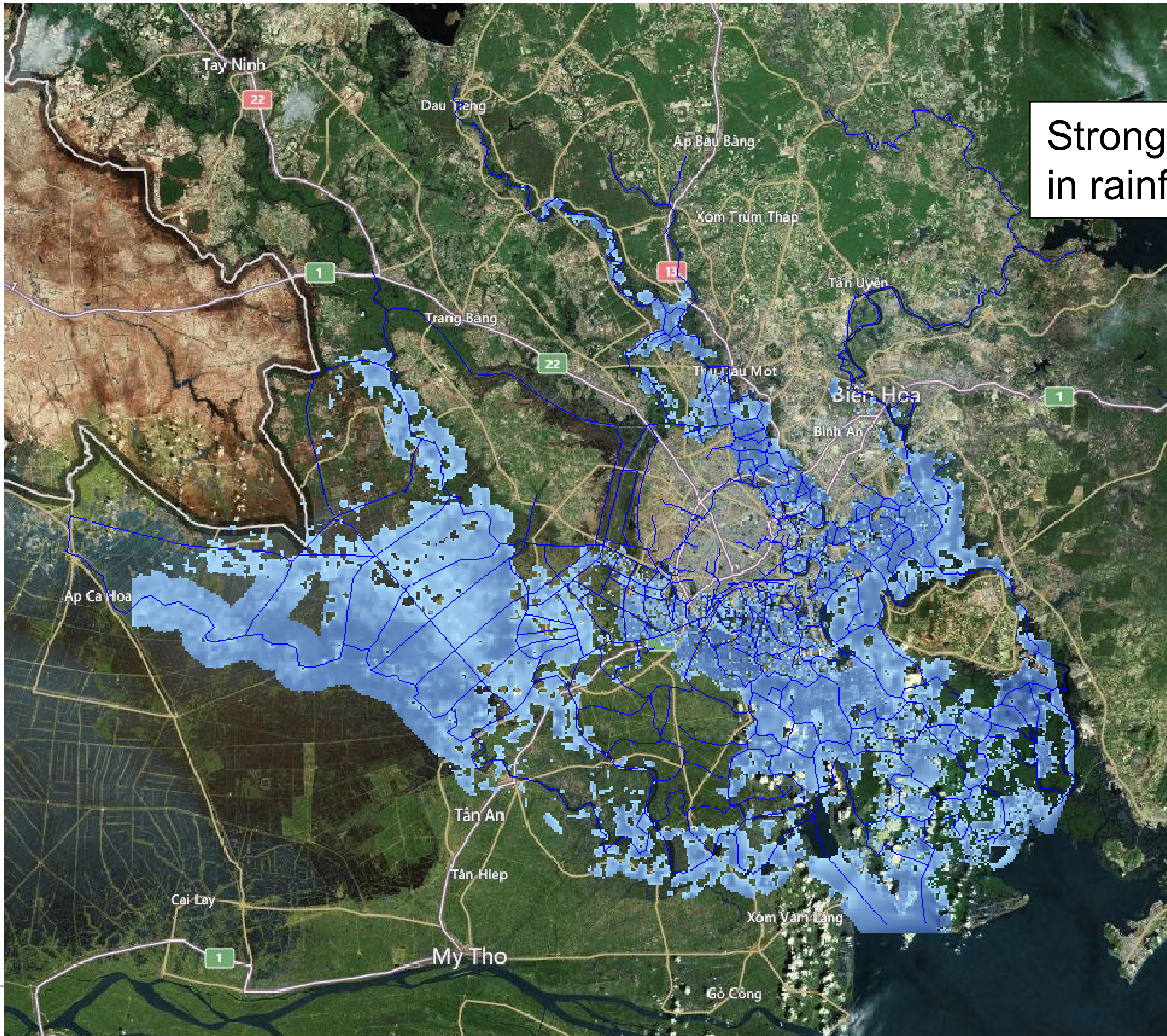
A few other examples: Hong Kong

Correlation between rainfall and surge during typhoons



Ho Chi Min City (Saigon)



Strong seasonal effects in rainfall and tide

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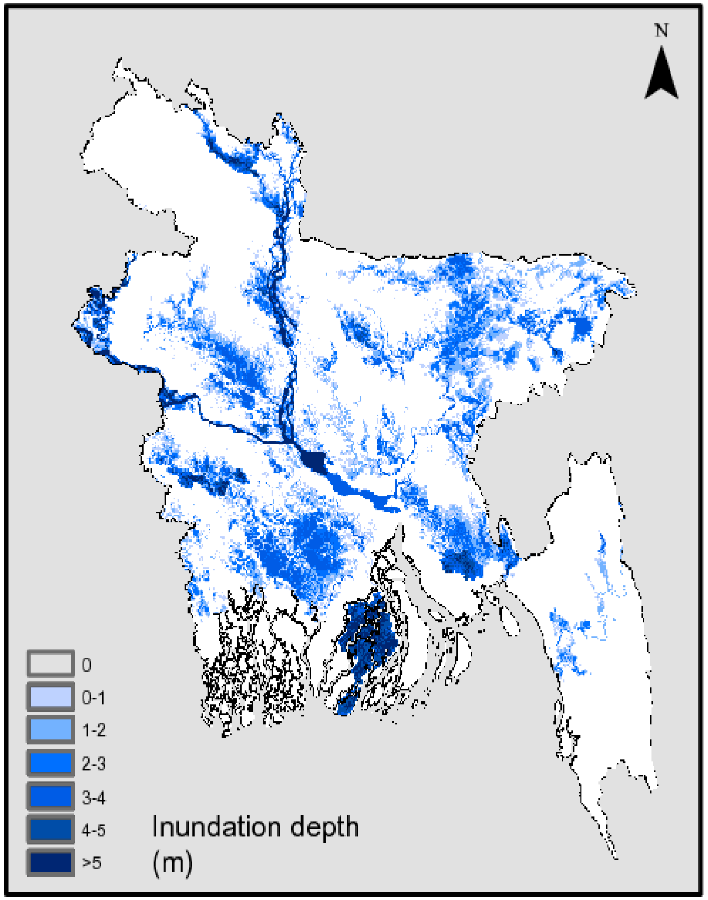
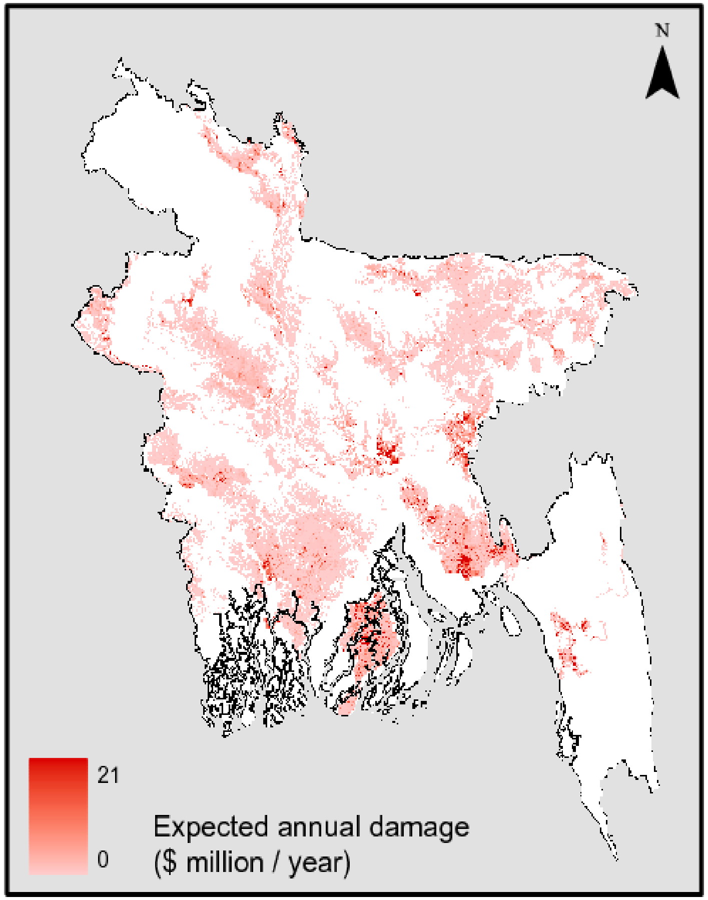
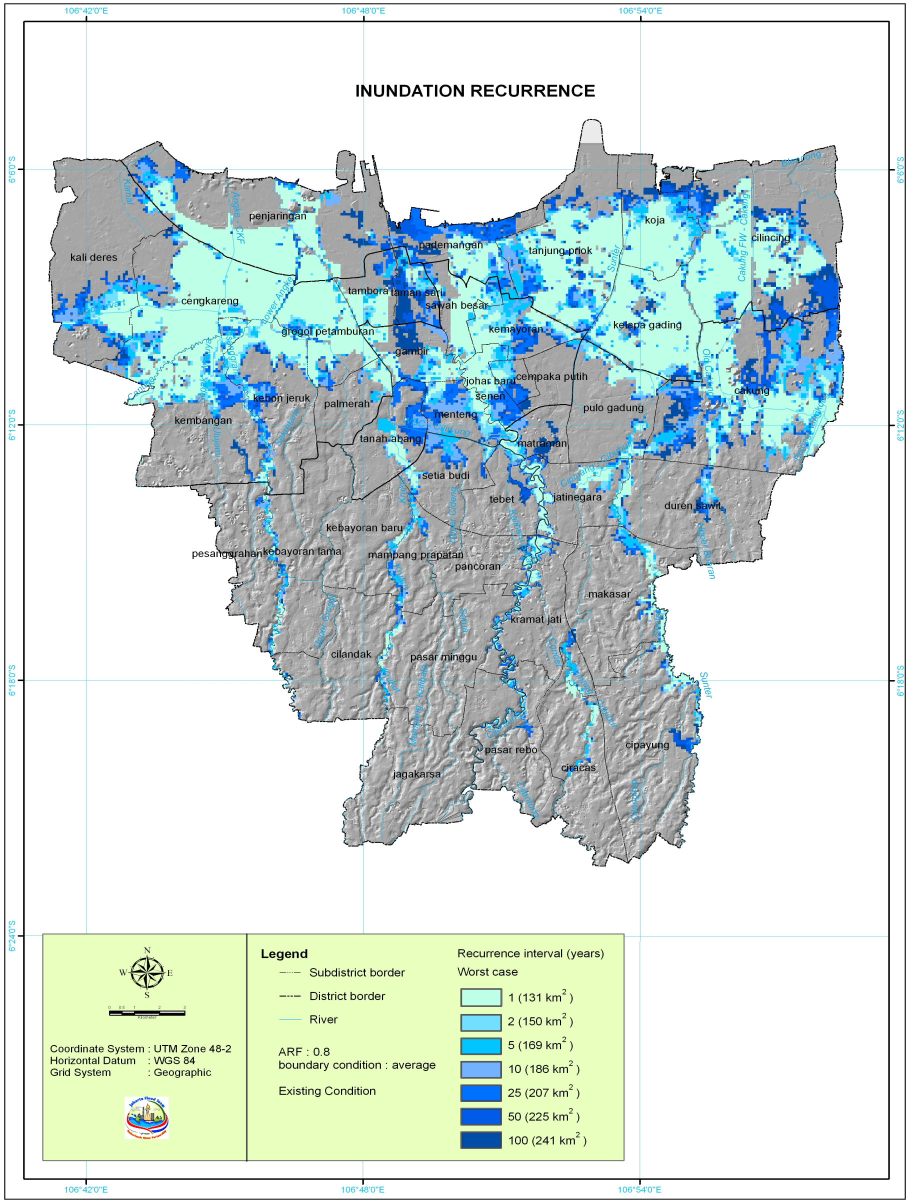
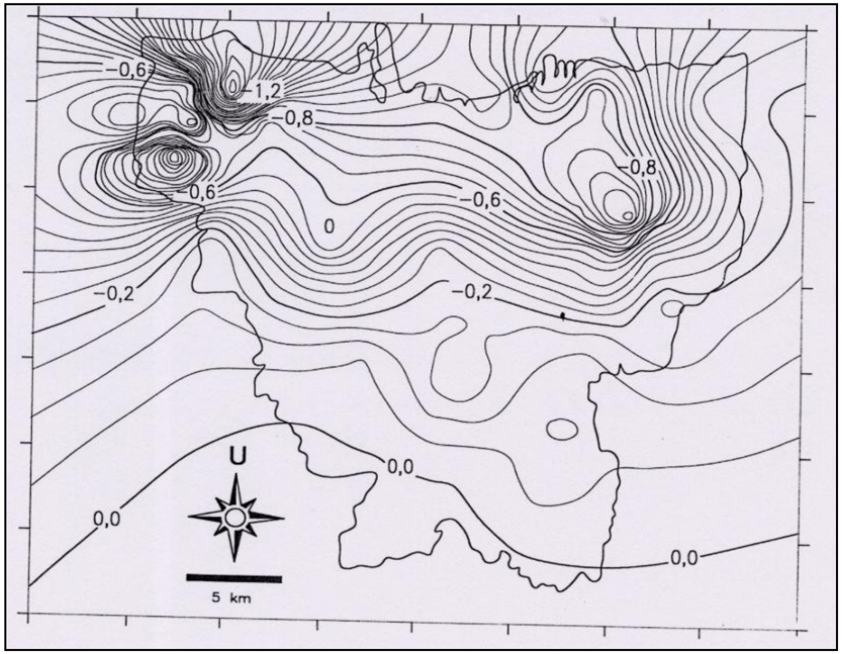
Bangladesh


N
0
0-1
1-2
2-3
3-4
4-5
>5
Inundation depth
(m)


N
21
0
Expected annual damage
($ million / year)

Jakarta – Indonesia





Land subsidence of several cm per year

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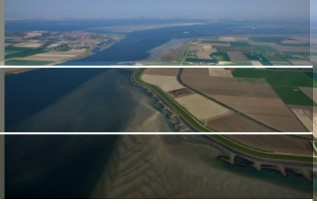
Conclusions



- Number of combinations of forcing variables in tidal river systems poses a computational challenge to PFHA
- Specific model is required for each situation (forcing variables and correlations)
- In the transition zone, often a large contribution from combinations of less than extreme values of the individual variables

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Thanks for your attention

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