Historic storms of the 18th century

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Introduction

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PhD thesis: Operational forecasts of morphological effects of storms

Links

http://citg.tudelft.nl http://www.deltares.nl
http://www.openearth.nl http://www.micore.eu

1 Coastal safety along the Dutch coast

2 Decades ahead

3 Days ahead

4 Centuries ago

Outline

1 Coastal safety along the Dutch coast

2 Decades ahead

3 Days ahead

4 Centuries ago

The Netherlands below sea level

Elevation

40% Of the Netherlands is below sea level.

How safe should it be?

Norm

Dutch safety standard of $1/10000$ (exceedance probability for the Holland Coast per year) is based on economic evaluation of the hinterland.

How to deal with safety?

- Risk management
  - Pro-action
  - Prevention
- Crisis management
  - Preparation
  - Response
  - Recovery

Outline

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Erosion -

Tide +=

Surge =

Waves =

Sea level +

Subsidence -

Figure: Possible changes affecting coastal safety

Erosion

Erosion

Coast is extending due to extensive nourishments.

Figure: Sand engine, source: Rijkswaterstaat/Joop van Houdt

Figure: Growth of coast at Katwijk, source: Kustlijnkaartboek 2011

Sea level rise

Relative sea level rise

Constant trend of 19cm/century

Paintings

Sea level trends in Venice.

Using paintings as a source for sea level rise estimates.

Figure: Sea level rise (source: D. Camuffo 2010)

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Operational modelling

Forecasts

Predicting coastal changes 3 days ahead.

Figure: Operational model for coastal morphology (Baart et al 2009)

Operational modelling

Forecasts

Improvements to several aspects of the operational coastal morphological model.

Figure: Improvements to several aspects of the operational coastal morphological model.

Improving the coverage

From local empirical model (applicable to 60%) to a general numerical model (applicable to 90%)

Figure: Duros 1D model versus XBeach 2D model, http://www.xbeach.org

Open Source models

Delft3D

Open source modules: FLOW, MOR, WAVE.

Figure: Delft3D simulation of Rhine rofi, source: De Boer, http://oss.deltares.nl

OpenEarth

Collaboration to share data model and tools.

Figure: Visualizations made with OpenEarthTools, http://www.openearth.eu

Operational modelling

Figure: Forecasting water levels and currents nearshore and erosion

Figure: Swimmer simulator

Response measures

Figure: Twee gebroeders, 1953

Figure: Research: Emergency measures Delfland, Walstra et al

movie

Figure: XBeach model of Petten met hyperstorm ($p < 1/10000$).

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How big is the $^1/_{10000}$ storm?

The size of the $^1/_{10000}$ storm.

Over 3m.

Figure: Confidence interval of storm surge for Hoek van Holland (van den Brink 2004)

How to reduce the size of the confidence interval?

The size of the confidence interval

$$\frac{1}{\sqrt{n}}$$

How to reduce the size of the confidence interval?

The size of the confidence interval

$$\frac{1}{\sqrt{n}}$$

How to get a bigger n?

- Pre-historic storms
- Historic storms
- Measured storms
- Modelled storms

Statistical methods

Peak over threshold

$$F_{(\xi,\mu,\sigma)}(x) = \begin{cases} 1 - \left(1 + \frac{\xi(x-\mu)}{\sigma}\right)^{-1/\xi} & \text{for } \xi \neq 0, \\ 1 - \exp\left(-\frac{x-\mu}{\sigma}\right) & \text{for } \xi = 0. \end{cases} \tag{1}$$

Needs high resolution (multiple measurements per day) time series.

Block maxima

$$F_{(\xi,\mu,\sigma)}(x) = \exp\left(-\left[1 + \xi\left(\frac{x-\mu}{\sigma}\right)\right]^{-1/\xi}\right) \tag{2}$$

$$F_{(\mu,\sigma)}(x) = e^{-e^{-(x-\mu)/\sigma}}. \tag{3}$$

Needs information about maximum per year (ordering).

Available data

Pre-historic	information from geological records (–1500)
Historic	information from letters, reports, paintings, flood stones (1500–1800)
Measured	information from measurements (1800–)
Modelled	based on assumptions (–)

Goal

The 3 biggest storms of the 18th century

Use historical records and give an estimate of the size of the biggest storms of the 18th century.

Ordering

Table: Storms of the 18th century

Year	Classification [a]	Order [b,*]
1715	D	5 [c]
1717	D	3
1741	/	4 [d]
1775	D	2 [e]
1776	C	1 [f]

[*] Because several different sized inches were used in the 18th century, it is not always clear what the exact metric translation is. That is why some of the notes below are given in inches. These values are only used to determine the ordering column. [a] Based on [1] A: very severe floods; B: heavy floods; C: less heavy floods; D: small floods. [b] For the Northern Holland coast [c] In Amsterdam "0.31m less than 1717", Harlingen "9 inch lower than 1717" [d] In Amsterdam and Rheede "has not been so high since 1717", In Amsterdam "7 inches lower than 1717", "3 inches less than 1717" [2], no comparison with 1715 was found [e] In Amsterdam "as high as 1717", Elburg "this flood is far higher than 1717", Delfshaven: floodstone: NAP +2.675 m [2] [f] Beulake (village drowned in 1776), "1 feet higher than 1775", Delfshaven "higher than 1775", floodstone: NAP +2.704 m[2]

The area of interest

Figure: Northern part of the Holland coast. Locations mentioned in presentation

The Christmas Flood of 1717

Source gallica.bnf.fr / Bibliothèque nationale de France

Figure: Flood map of the 1717 Christmas Flood

Data for the 1717 storm: paintings

Figure: Paintings from Egmond aan Zee between 1600–1750

- Water levels from Amsterdam
- 1 floodstone
- Letters, poems, reports
- Maps
- Paintings

Using paintings as a data source

Figure: Estimating painter reliability

3D model of Egmond at 1717

Figure: Reconstruction of erosion in the period 1600–1717

Post storm profile

Figure: Post storm measurements (1718).

Pre and post storm profile

Figure: Estimating the pre and post storm profile. Inverse model the magnitude of the storm.

The storm of November 1775

Figure: Paintings of the 14–15 November storm at Scheveningen

Data for the 1775 storm: shell deposits

Figure: Shell deposits found after the storm of November 2007, OSL dating by Cunningham, pictures: M. Bakker

Modelling the 1775 storm

Figure: Modelling the storm run up, source A. Pool

Modelling the 1775 storm

Figure: Modelling the storm run up, source A. Pool

The storms of the 18th century

Table: Estimated magnitude of the three largest storms of the 18th century

Year	Water level	Wave height	Wave period
1717	4.2 m	8.4 m	13.3 s
1775	4.6 m	8.8 m	13.9 s
1776 [a]	4.9 m	9.1 m	14.3 s

[a] Estimated as the water level of 1775 plus 0.29 m based on the floodstones, see Table 1

The updated confidence interval

Figure: 30% smaller confidence interval using the Gumbel method. Higher estimate 1.4 with bigger confidence interval using the GEV method.

Conclusions

Can we reduce the size of the confidence interval of the $1/10000$ surge?

Only if we assume a constant shape.

Are paintings useful as a data source?

Yes but multiple paintings should be used because they have a low precision.

References

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Statistical methods for the risk-based design of civil structures.

PhD thesis, Delft University of Technology, January 2000.

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Technical Report 2003.08.1, Aqua Systems International, August 2003.