Hydrodynamic and hydrological modelling to support the operation and design of sea ports

Data needs and examples

Martijn de Jong (port/nautical requirements, waves, currents)
Sofia Caires (mean and extreme metocean climate and projections)

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Scoping workshop on Sea Ports and Climate Change
4/5 March 2013 – Brussels
Deltaires

- Dutch-based
- research institute and specialist consultancy
- water, soil and the subsurface
- advanced expertise to help people live safely and sustainably in
  - delta areas,
  - coastal zones
  - and river basins.

Typical problems

- Design and operation of a port
- Breakwater design
- Ship manoeuvering and mooring
- Wave penetration
- Assessment of water defences
- Environmental impact study
- Coastline evolution
What generally needs to be computed

- Mean and extreme of wind, current (patterns), water level and waves climates at several locations in and around the port

What input data are generally required

- Offshore mean and extreme metocean conditions, discharges, tides, sea level (based on measurements, hindcasts or reanalysis)
- Bathymetry

Assessing the effects of climate change requires new projections of several variables at a project location, representing similar types of statistics (means/extremes), but then updated to represent the altered situation.
Monaco land reclamation

wave conditions   flow conditions   ship manoeuvring   edge structures   beach impact

Deltaxres
Monaco land reclamation

Example 1/10

Required input:
- Measurements for calibration
- Offshore wave means and extremes
- Wind mean and extremes
- Boundary currents
- (extreme) Water levels
Design sea defence Maasvlakte 2

- large port extension into the North Sea
- pebble beach combined with (partly) submerged berm/dam of blocks
- 1:10000 year design storm
- aim: verify design, provide recommendations for the design
- attention to feasibility
- scale model tests on different scales
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**Required input:**
- Offshore wave extremes
- Morphology
Nautical safety and accessibility Port of Rotterdam

- 3D flow modelling Maasvlakte 2
- procedure for nautical evaluation of cross currents and gradients along entrance channel
- during different stages of construction: provide information of the present current information to pilots (FEWS-viewer)
3D flow modelling Maasvlakte 2

procedure for nautical evaluation of cross currents and gradients along entrance channel during different stages of construction: provide information of the present current situation to pilots (FEWS-viewer)

Required input:
- River discharges mean conditions
- Wind mean conditions
- Tides
Construction of Gijon caisson breakwater

- outer breakwater to be constructed
- 30 caissons, 50m length each
- placed on bed of rocks

- problem: local wave climate only allows 40 working days a year (for assumed workability limit, $H_s = 0.8$ m, $T_p = 8$s)
- construction time over 2 years, too long, too costly

- Aim: perform detailed study to widen workability window by determining workability limit in detail
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workability limit in detail

Required input:
- Offshore mean (operational) swell and
wind-sea (height, period, direction)
conditions
- Mean wind conditions

Means: swell, direction, period!!!
Channel study, Astute Submarines, UK

Example 5/10

Required input:
- **What**: Wind-sea, swell, period and direction, mean conditions
- **Where**: In the region offshore and along the channel towards the port
Deltarès-scope:

- modelling of waves and currents
  - determine design conditions
- modelling of coastline development
  - determine impact on surrounding coast
- setup measurement campaign
  - calibrate models
- develop prediction tool
  - estimate downtime of facilities
Port development Port of Sohar, Oman

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- modelling of waves:
  - determine design conditions
- modelling of coastline development:
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Required input:
- Offshore mean and extreme wave conditions
- Mean and extreme wind conditions
- Boundary currents
- Morphology

Example 6/10
• Quays and sea defenses in the area
• Height information of buildings etc.
• Aim: assess extent (and depth) of flooding areas and related risks
• Dependent on design water levels
• Increased water levels due to climate change?
Flooding of quays (1:10000 years)

Example 7/10

- Quays and sea defenses in the area
- Height information of buildings etc.
- Aim: assess extent (and depth) of flooding areas and related risks
- Dependent on design water levels
- Increased water levels due to climate change?

Required input:
- Offshore extreme wave and water level conditions
- Extreme wind conditions
- Boundary currents
Smart Fairways, optimising Inland Waterway Transport (IWT)

Electronic Navigation Charts (ENC) with predicted:

- Water depth (WAQUA, Delft3D)
- Current velocities (WAQUA)
- Bridge heights (SOBEK)
- Lock waiting times (lock master)

Example 8/10

ENC with ship positions, channel, etcetera

Map of the Netherlands with all navigable waterways and bridges
Electronic navigation charts with predicted:

- Water depth (WAQUA)
- Current velocities (WAQUA)
- Bridge heights (SOBEK)
- Lock waiting times

**Required input:**

- River discharge extremes (high and low) (larger extremes in the future due to climate change?)
- River morphology
Wave penetration in harbours

Example 9/10

General examples, different wave models

large scale

small scale
Wave penetration in harbours – complex issues

Example 9/10

Numerical simulations

- Analysis of measurement data

Model validation

1) Extreme conditions for design
2) Mean wave conditions for moored ships

Insights into cause of hindrance
(complex combination of wave+current phenomena)
Complex wave penetration issues

1) extreme conditions for design
2) Mean wave conditions for moored ships

Required input:
- Offshore mean and extreme wave conditions (preferably spectral, wave periods are important)
- Mean and extreme wind conditions

Model validation

Insights into cause of hindrance
(complex combination of wave+current phenomena)
Ship manoeuvring
Required input:

- **Resolution**: mean/operational: 1 to 2% exceedances) conditions

- **What**: swell and wind-sea (height, period, direction), wind, currents (including river discharges)

- **Where**: Whole region
Summary

Needs

- Offshore wave (height, **period**, direction) conditions (mean, extreme)
- Wind speed and direction (mean, extreme)
- Water levels (mean, extreme)
- Discharges (mean, extreme)
- Temperature (mean, extreme)
- Salinity (mean, extreme)
- Morphological changes

Sources

- Global (IPCC) vs regional scenarios
- Global (CMIP5, no waves) vs regional models
- Numerical vs Statistical downscaling

Uncertainties
Stability pipeline protection Ichthys gas field (Au.)

- stone protection on top of gas pipe between offshore gas field and the port of Darwin, Australia
- protect pipe against anchors, remain stable under cyclone conditions (1/200 year)
- tests in wave basin (Atlantic Basin, scale 1:17.5 to 1:22.5)
- tests in geo-centrifuge (scale 1:80, so at 80g) to simulate pulling the anchor through the rock
- aim is to optimised the required amount of stone to be used → big construction savings
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- aim is to optimise the required amount of stone to be used for anchor drag testing and achieve big construction savings.

Required input:
- Metocean extremes covering the whole region.

(anchor drag testing, model in geocentrifuge, rock berm models in Atlantic Basin)