Wind and wave modeling in an operational warning system against flooding

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Storm on the IJsselmeer

Flooding of coastal areas

Contents

- Area of interest
- Wind modeling
- Water level modeling
- Wave modeling
- Wave run-up modeling
- Operational aspects
- Further developments

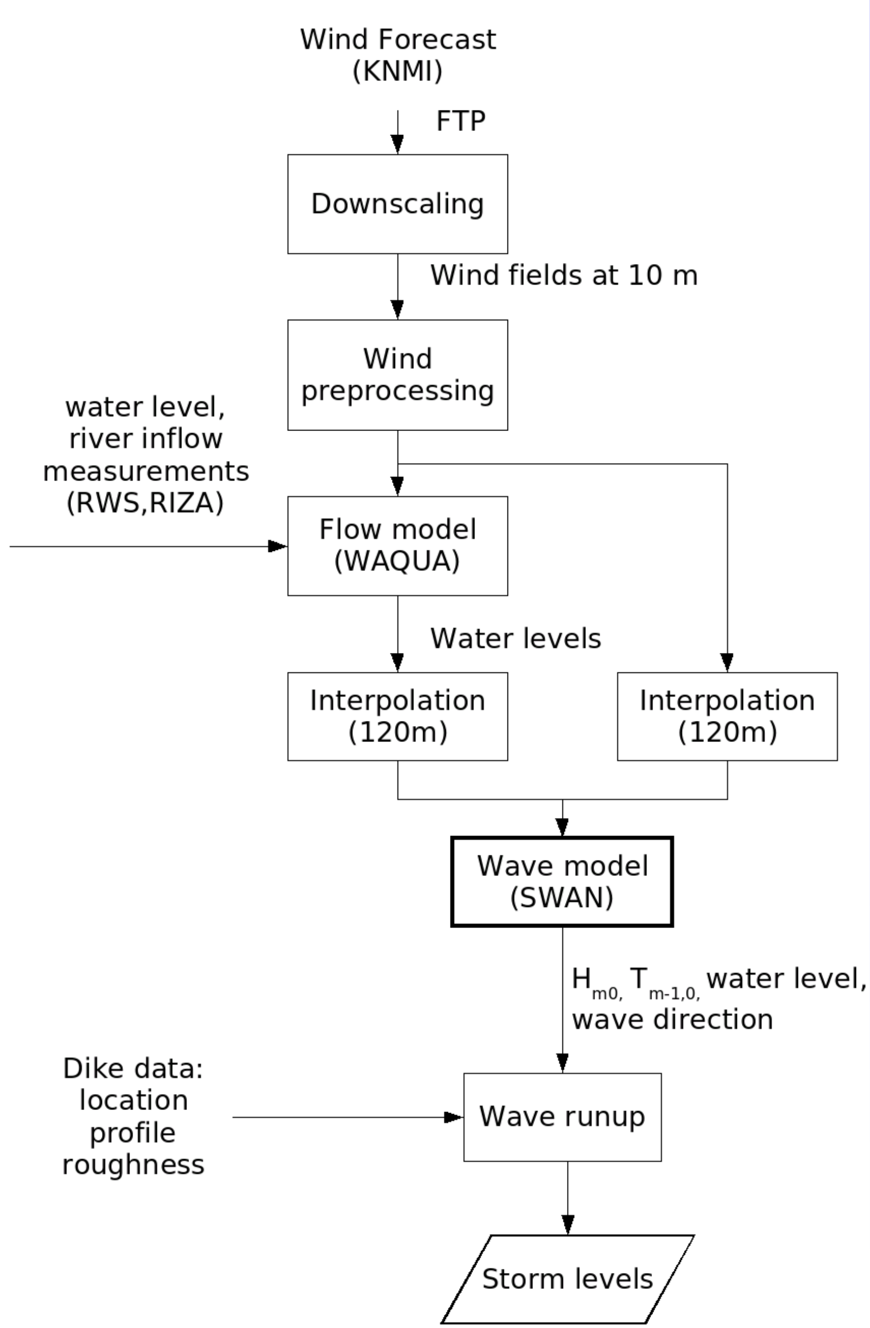
Warning system against flooding for lakes in the IJsselmeer area

General framework of operational warning system

Repeating cycle of actions (every 3 hours)

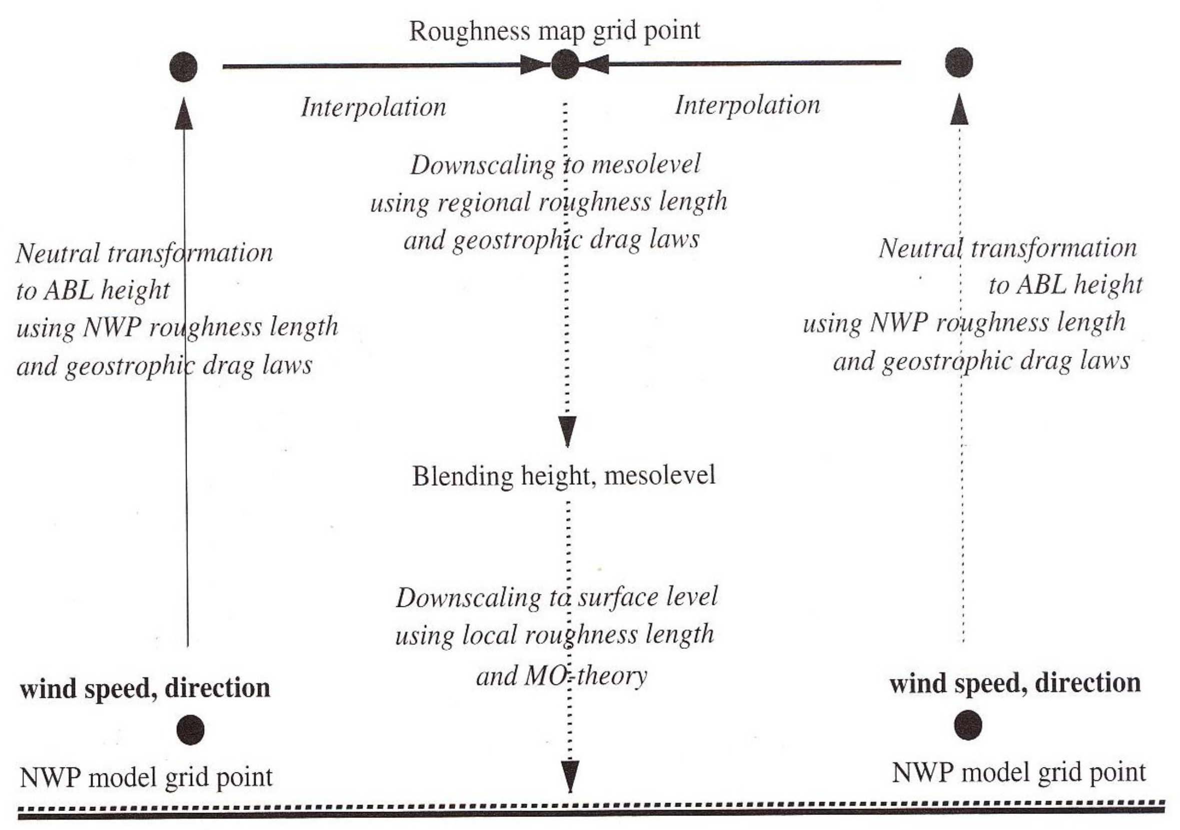
- Weather forecast
- Downscaling of wind
- Water level forecast
- Wave forecast
- Wave run-up simulation
- Storm level = maximum water level reached on the dike
- If storm level > alarm level

Issue of warnings to dike authorities!



Structure of operational warning system

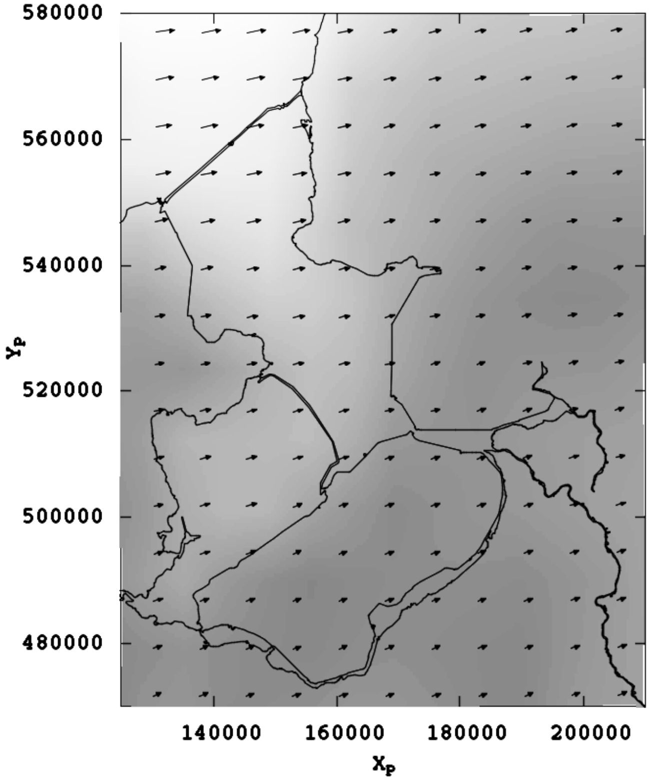
Principle of downscaling



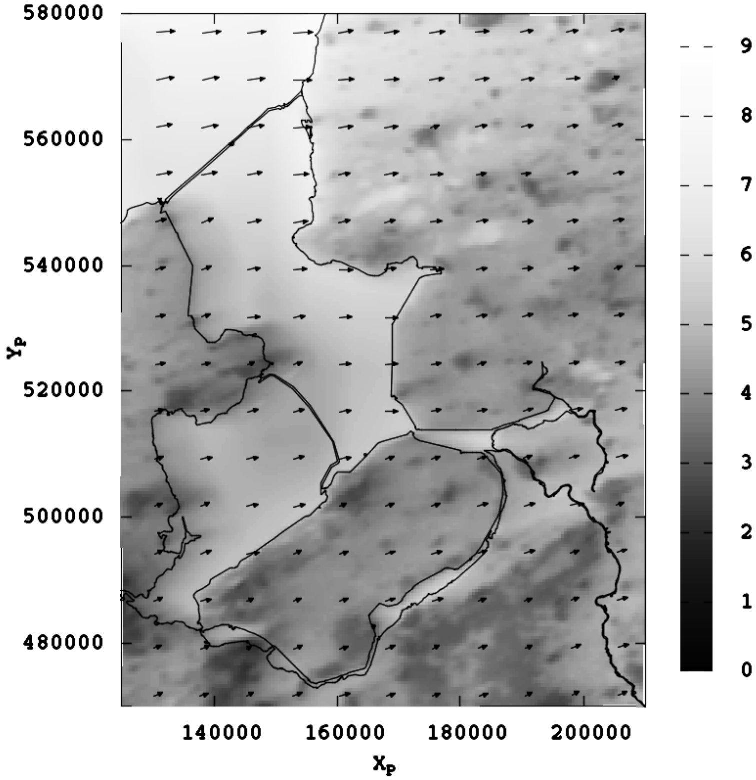
Job Verkaik (2006)

Example of downscaling

Δs=11 km



Δs=500 m



WAQUA modelling

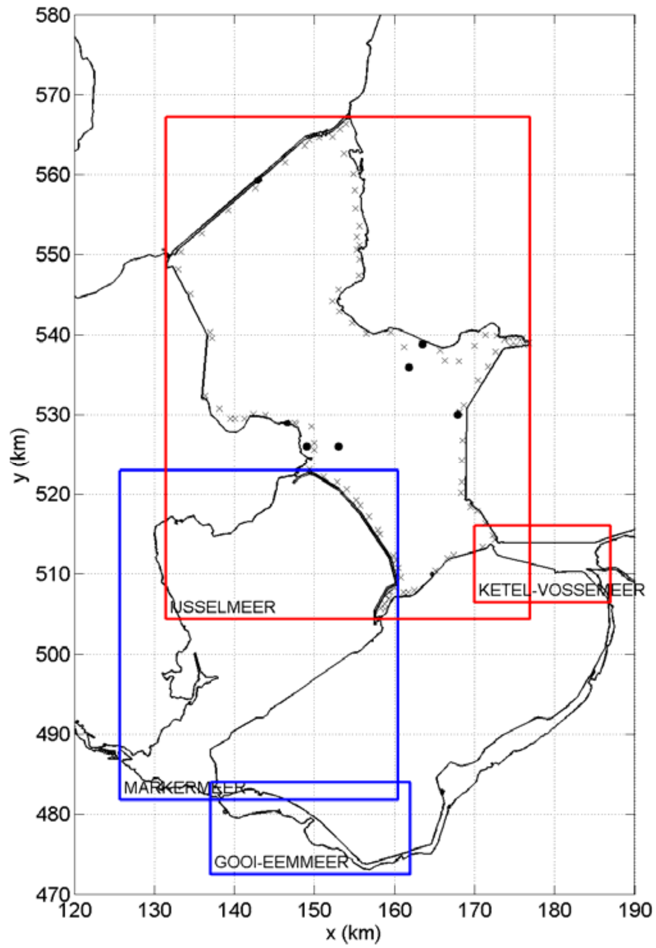
- Curvi-linear grid with varying resolution from 10m to 1000m
- 2 separate models
  - IJsselmeer+Ketelmeer+Vossemeer
  - Markermeer+Gooimeer+Eemmeer
- Driven by expected water levels, river discharges and downscaled winds
- 24 hours hindcast + 48 hours forecast
- No data-assimilation
- Output of water level fields

SWAN implementation

- SWAN settings
- Computational grids & nesting
- Bottom topography
- Grid resolution
- Convergence criteria
- Correction factors
- Input & output
- Uses water level from Waqua modelling
- Uses wind from downscaling

SWAN settings

- Version 40.51 (Release August 2006)
- Stationary mode (instationary mode takes too long Claessens et al., 2002, Banff)
- t = +3,+6,+9,+12,+18,+24, +36, +48 hours and at moment of highest wind speed
- 2 sets of nested grids for each water system
- Output:
  - fields of wave height, period and direction
  - tables of wave height, period, direction and water level for run-up module



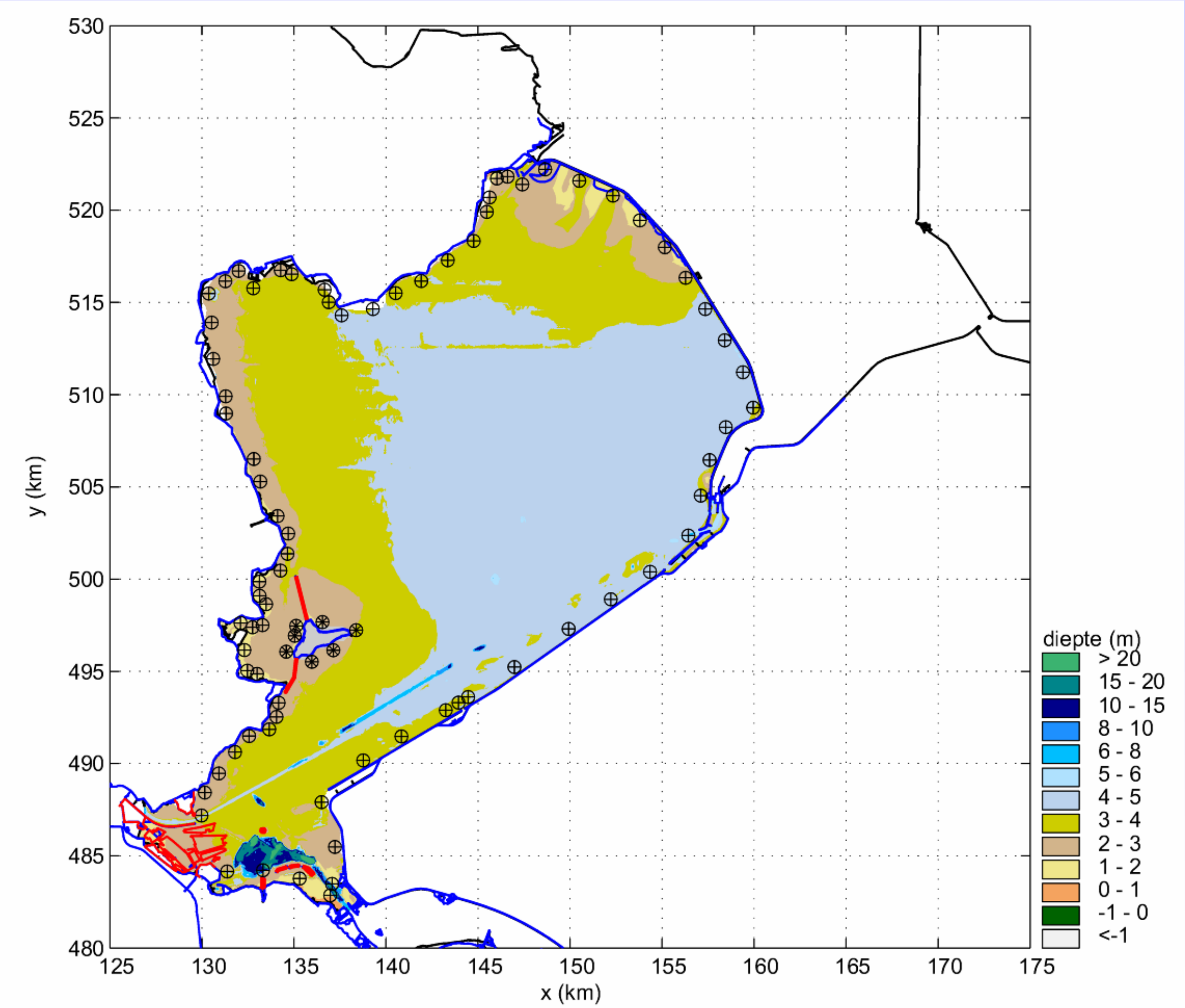
SWAN computational grids, output locations and measurement locations (only in IJsselmeer)

2 sets with nesting

IJsselmeer → Ketelmeer-Vossemeer

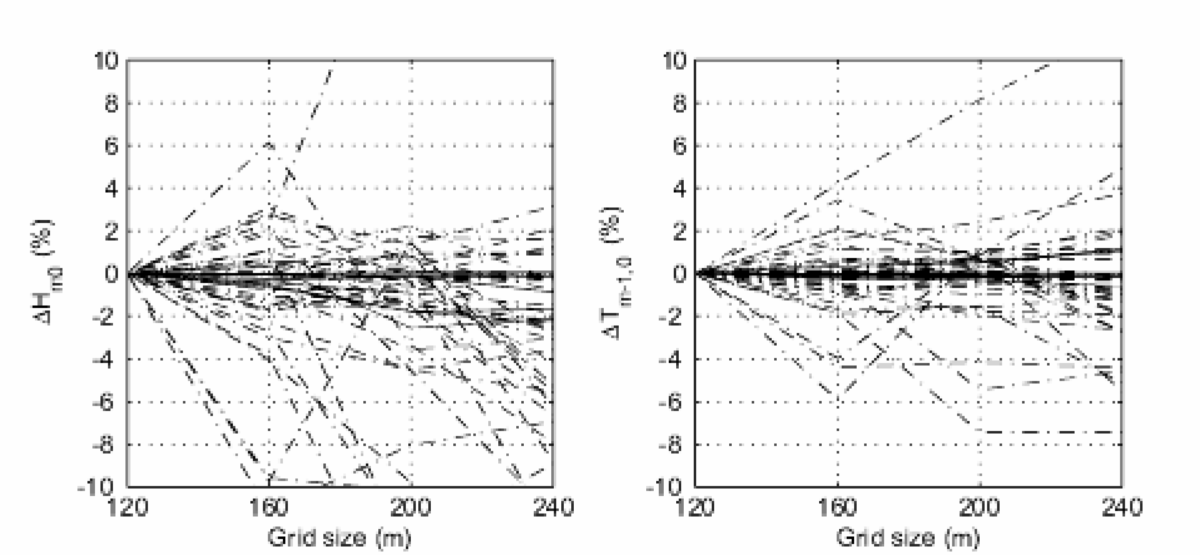
Markermeer → Gooimeer-Eemmeer

SWAN bottom topography dams and output points

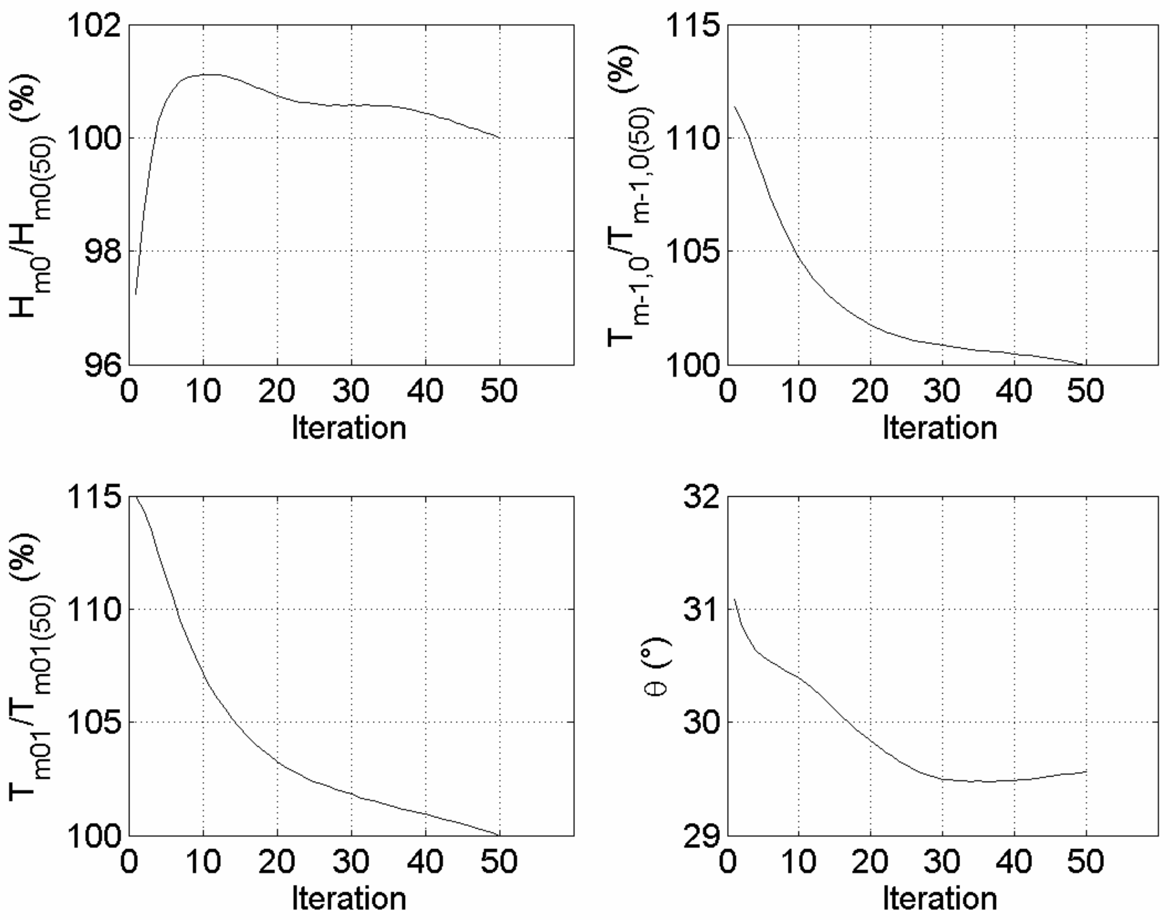


SWAN grid resolution

- Test simulations on different resolutions IJsselmeer: 120 m, 160 m, 200 m, 240 m
- Estimation of discretisation error
- Variation of relative error with grid size (normalized by results of smallest resolution)



SWAN convergence behavior



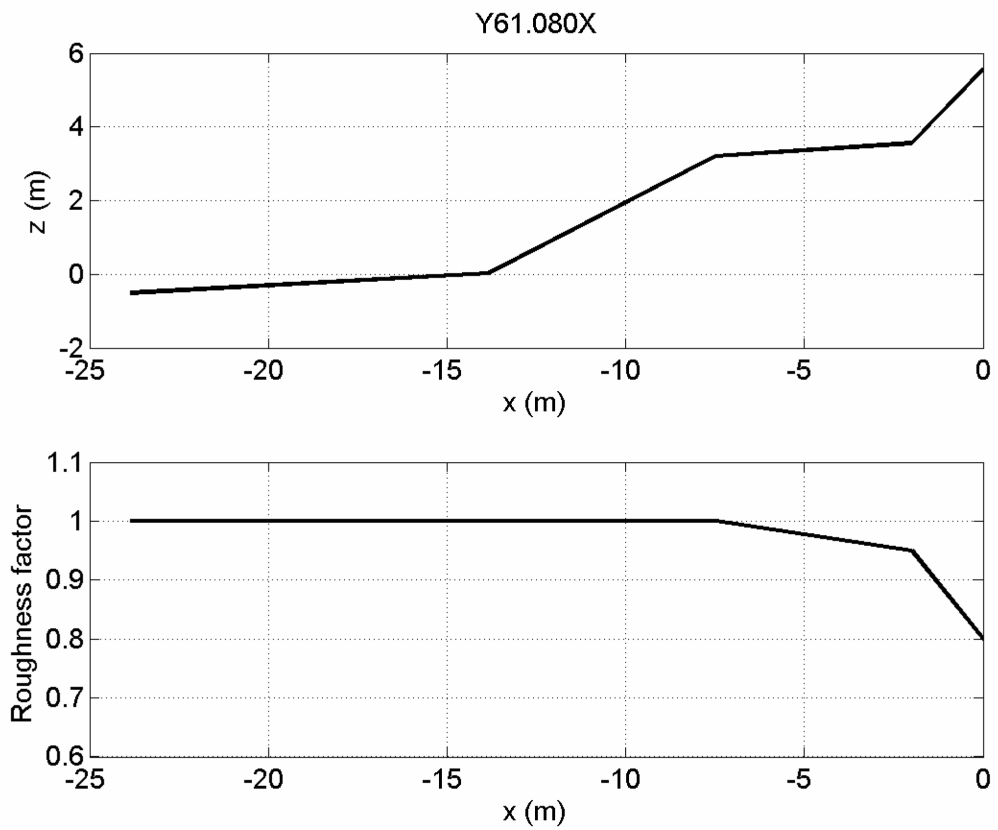
50 iterations are needed

SWAN correction factors

- SWAN settings trade-off between accuracy and efficiency
- Systematic prediction error depends on these settings
- Predicted and measured data from storm periods were used to derive correction factors for H_{m0} and $T_{m-1,0}$
- Distinction between high (H_{m0} > 1m) and low waves

Wave runup

Dike profiles



Schematized dike profile and roughness factor

Wave run-up module

- Input from SWAN tables:

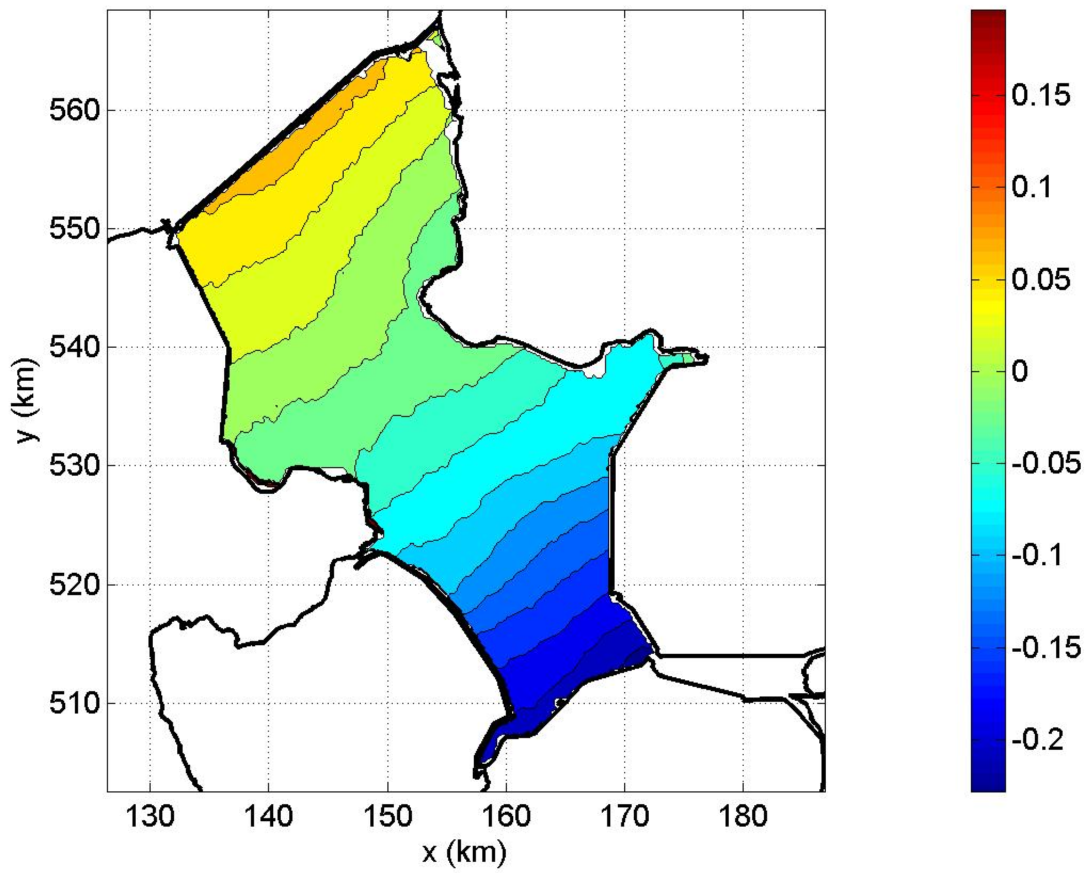
  wave height (H_{m0}), period ($T_{m-1,0}$),

  direction (θ) and water level (h)
- Run-up = f(H_{m0}, $T_{m-1,0}$, $|\theta - \theta_{\perp}|$, h)
- Storm level = water level + run-up
- Check storm level against alarm level

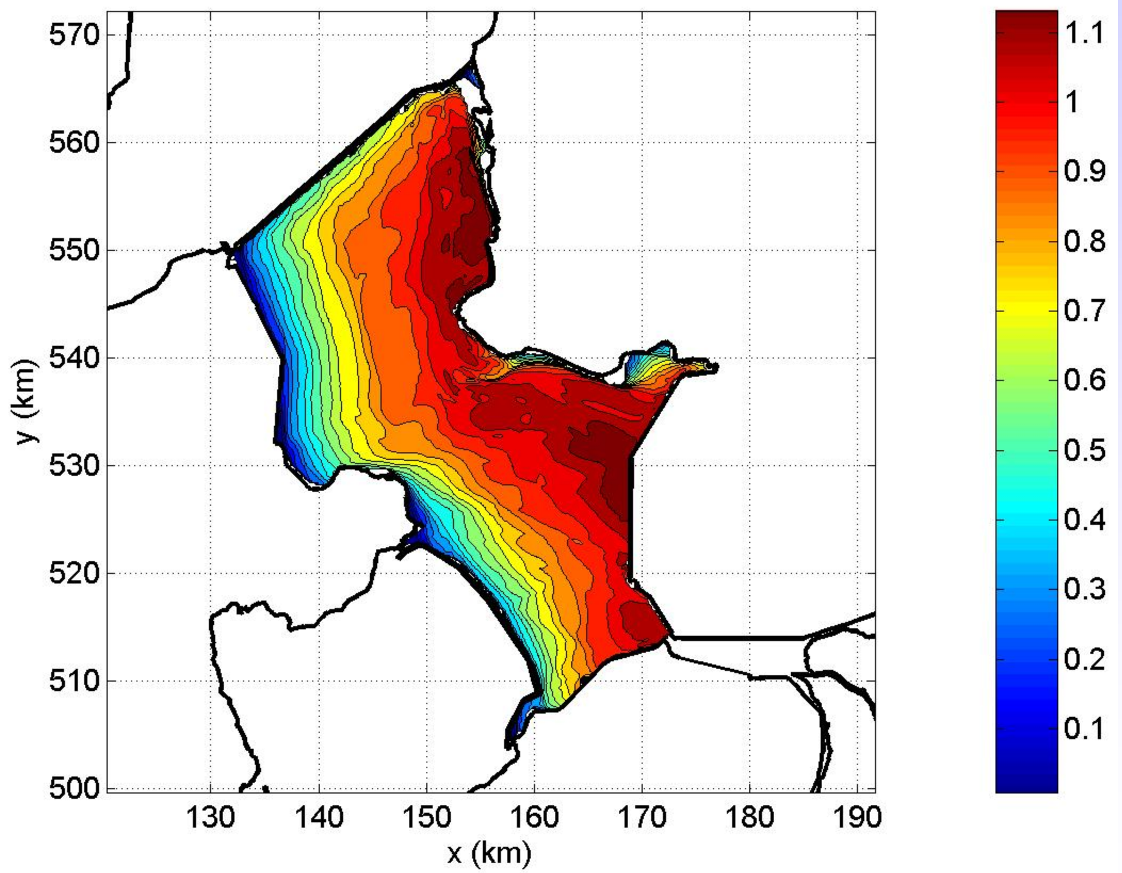
Operational aspects

- Warning systems composed of existing stand-alone modules (simplifies updating)
- Automatic generation of input files from templates
- Key information stored at one location
- Efficient interfacing between modules
- Transparent directory structure
- Parallel execution of tasks
- WAQUA release June 2006
- SWAN version 40.51
- Linux cluster of 8 PC's (Pentium 3.0 GHz, 1 GB RAM)
- Linux distribution Slackware 10.1, kernel 2.4.31

Examples of operational warning system: water level



Wave height on IJsselmeer



Quality of the warning system

- Verification of each module:
  downscaling, WAQUA, SWAN
  wave run-up
- Overall verification requires monitoring for long period time: collect **measurements** of wind, water level, waves, and wave run-up in all lakes
- Statistical analysis of results
- Calibration of SWAN and/or fine-tuning of correction factors

Future developments

- Grid nesting along shallow boundaries
- Finer spatial resolution
- SWAN instationary
- Speed-up of SWAN (new first guess)
- Wave-current interaction
- Fine tuning of SWAN
- Extending the number of processors
- Implementing fail safe and fall backup options

Conclusions

- Operational warning system has been build
- Automatic retrieval of wind fields from KNMI
- Downscaling of winds to 500 m resolution
- WAQUA flow model to derive water level fields
- SWAN wave model
- Wave run-up module
- Automatic generation of warnings if threshold storm levels are exceeded