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Benchmarking database for
Unibest-TC and Delft3D-MOR

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A benchmarking database for UNIBEST-TC and Delft3D-MOR has been implemented with the objective to facilitate testing of various model settings. The database (Chapter 2) has been sub-divided into separate datasets, in which a number of cases are defined. This structure implies that running a simple script file in a case directory automatically runs the model and produces plots that compare the model output with available measurements at predefined moments and places. The clear database structure allows a user to straightforwardly insert a new dataset. Up to now, 11 data sets have been implemented for UNIBEST-TC, as described in Chapter 3 and 4. The data sets include both laboratory and field measurements. The majority of the datasets have been selected for their applicability to enable the testing of various hydrodynamic physical processes, such as wave height, and cross-shore and longshore velocity. Various other also include sediment transport information and profile development. Besides comparison of model results and experiments, the benchmarking database facilitates statistical error analysis, of which various examples are shown in Chapter 5. The benchmarking database for Delft3D-MOR is described in Chapter 6. A list of conclusions and recommendations is given in Chapter 7.
Contents

1 Introduction
   1.1 General
   1.2 How to use this guide

2 Benchmarking database for UNIBEST-TC
   2.1 Introduction
   2.2 Structure
      2.2.1 Case directory
      2.2.2 Model directory
      2.2.3 Additional files
   2.3 Step-by-step guide to entering a dataset

3 Benchmarking datasets: 1. Laboratory measurements
   3.1 Overview
   3.2 Model set-up
   3.3 Battjes and Janssen (1978)
      3.3.1 Dataset description
      3.3.2 Model set-up
      3.3.3 Results
   3.4 Van der Meer (1990)
      3.4.1 Dataset description
      3.4.2 Model setup
      3.4.3 Results
   3.5 Stive (1985)
      3.5.1 Dataset description
      3.5.2 Model setup
      3.5.3 Results
   3.6 Arcilla et al. (1994), Roelvink and Reniers (1995)
      3.6.1 Dataset description
      3.6.2 Model setup
      3.6.3 Results
   3.7 Reniers et al. (1997)
3.7.2 Model set-up .................................................................15
3.7.3 Results ............................................................................15

3.8 Boers (1996) ........................................................................16
3.8.1 Dataset description .........................................................16
3.8.2 Model set-up .....................................................................16
3.8.3 Results .............................................................................16

4 Benchmarking data sets: 2. Field measurements ......................17
4.1 Overview .............................................................................17
4.2 Hotta and Mizuguchi (1980) ..................................................17
  4.2.1 Dataset description ..........................................................17
  4.2.2 Model setup .....................................................................18
  4.2.3 Results .............................................................................18
4.3 Ebersole and Hughes (1987) ..................................................18
  4.3.1 Dataset description ..........................................................18
  4.3.2 Model setup .....................................................................18
  4.3.3 Results .............................................................................18
4.4 Egmond Hydrodynamic ........................................................18
  4.4.1 Data set description ..........................................................18
  4.4.2 Cases and model set-up .....................................................19
  4.4.3 Results .............................................................................21
4.5 Egmond Morphodynamic .....................................................23
  4.5.1 Cases ..............................................................................23
  4.5.2 Measurements .................................................................23
  4.5.3 Reference model ..............................................................24
  4.5.4 Results .............................................................................24
4.6 EgmondLong .................................................................25
  4.6.1 Dataset description ..........................................................25
  4.6.2 Model setup .....................................................................25
  4.6.3 Results .............................................................................25

5 Statistical analysis .....................................................................26
5.1 Tool ....................................................................................26
5.2 Model Performance Statistics ..............................................27
5.3 Examples .............................................................................28

6 Benchmarking database for Delft3D-MOR ..................................31
6.1 Introduction .........................................................................31
6.2 Coast3D-data ........................................................................................................31
6.3 Inventory of other datasets..................................................................................31

7 Conclusions and Recommendations......................................................................32

7.1 Summary..............................................................................................................32
7.2 Reference model performance ..........................................................................32
7.3 Recommendations..............................................................................................33
    7.3.1 UNIBEST-TC ..................................................................................33
    7.3.2 Delft3D-MOR ..................................................................................34

8 References..............................................................................................................35
1 Introduction

1.1 General

Numerical models have become one of the corner stones of coastal engineering and are often applied tools to obtain answers or solutions for a specific coastal question or problem. Essential phases in a proper modelling framework are calibration and validation. Calibration involves model parameter tuning such that optimum agreement with measurements is obtained. During the validation no optimisation of model performance is allowed, but the model with settings obtained during calibration is tested on other data. This gives an indication of the model’s predictive capabilities for the problem under consideration.

Until recently, various model settings and model versions were calibrated and validated on different data sets, thereby obscuring model performance in general. To overcome this, a database with existing laboratory and field data sets was constructed for the process-based morphological models UNIBEST-TC and Delft3D-MOR with the aims to

- integrate model and measurements,
- facilitate easy testing of model settings and versions against a wide range of conditions, and
- identify shortcomings in understanding of physical processes, both considering model formulations and measurements.

The database is accompanied by a Statistical Analysis Tool, which allows to quantify model-data differences (see Walstra, 2000 for more details).

This report describes the database structure, the various implemented data sets and an example on how the database can be used with different model settings. It finalizes with a list of recommendations for further research.

1.2 How to use this guide

The database benchmarking for UNIBEST-TC is described in Chapters 2 - 5.

Chapter 2: Benchmarking database for UNIBEST-TC

This chapter describes the database structure and outlines how a new data set can be implemented.

Chapter 3: Benchmarking data sets: I. Laboratory measurements

Here, the implemented laboratory data sets are discussed. The set-up of the cases and runs included per data, and the outcome of a comparison of model results with the data is described. For this particular project, a ‘basic’ model version has been developed. To show
how the database can be used with different model settings, the model-data comparison is also provided with the same version, but now excluding the effect of breaker delay.

Chapter 4: Benchmarking data sets: 2. Field measurements
This chapter is devoted to a description of the implemented field data sets and the corresponding model-data comparison. Special attention is given to data set at Egmond obtained in the framework of the Coast3D project.

Chapter 5: Statistical analysis
As mentioned above, the database is accompanied by a Statistical Analysis Tool (SAT) which allows to quantify model-data differences. With SAT the effect of the improvement or reduction in model skill for different model settings can be easily quantified. Chapter 5 provides examples on the use of SAT.

The database benchmarking for Delft3D-MOR is described in Chapter 6.

Chapter 6: Benchmarking database for Delft3D-MOR
This chapter lists an overview of the available data sets in the database for Delft3D-MOR.

Finally, a summary of the report, a list of conclusions for the reference performance of UNIBEST-TC and a list of recommendations for further research are provided in Chapter 7.
2 Benchmarking database for UNIBEST-TC

2.1 Introduction

UNIBEST-TC is a module of the program package UNIBEST, which is an acronym for UNiform BEach Sediment Transport. The TC module has been designed to compute cross-shore sediment transport and the resulting profile changes along a coastal profile of arbitrary shape under wave attack. Variation in wave- and tide-induced longshore transport rates can also be accounted for. Main applications are the simulation of sand bar dynamics and seasonal profile changes, as well as the design of beach nourishment schemes. Bosboom et al. (2000) and Walstra (2000) provide a technical reference manual and user guide, respectively.

The benchmarking database of UNIBEST-TC is intended to include datasets of various tests (field and laboratory) against which the model can be tested automatically for a wide range of settings. The datasets that will be incorporated in the database should enable a complete qualification of the accuracy of the description of the implemented physical processes and the accuracy and reliability of the final results: the computed longshore sediment transport and the predicted profile development.

The installation of the database (provided on the CD-ROM) involves a simple copying of the entire contents of the CD-ROM to the desired directory on a PC. Because running the model will produce new files, sufficient hard-disk space should be available. The database cannot be run from the CD-ROM itself or form a network driver for which the database user has no write permission.

2.2 Structure

The majority of the datasets that have already been included in the database have been selected for their applicability to enable the testing of the hydrodynamic physical processes. The structure of the database is aimed at facilitating a simple and transparent comparison between measurements and model predictions. The database has been sub-divided into separate datasets, in which a number of cases are defined (see Figure 2.2.1).

2.2.1 Case directory

Data in the case directories is stored in the simple and transparent TEKAL-format. Each data file contains only one physical parameter. The TEKAL-format comprises one data block with two columns. The first column contains the x, z or t and the second column the parameter values. File names are standardised:

- `<param>.tek` for f(x) (not timedependent)
- `<param>.Xxxx.tek` for f(z) or f(t) at location xxx
- `<param>.Tttt.tek` for f(x) at time ttt
2.2.2 Model directory

The model directory contains the input files needed to run UNIBEST-TC (e.g. UNIBEST-TC input file, boundary conditions, etc.). It also contains the output files produced by UNIBEST. Furthermore it contains some essential files that are needed for the automatic comparison of model output and available (field) measurements (e.g. params.inp, params.out, plotdef.inp, run.bat). Finally the model directory is also the directory where one can find the results of the comparison process in the form of postscript formatted pictures.

2.2.3 Additional files

To actually perform the comparison between model output and measurements some extra files and programs are needed. Besides Matlab that is needed for the plotting, some custom made routines are needed that extract the necessary information from the UNIBEST-TC output files (rdft.exe, rdfxt.exe, rdvert.exe). Since the necessary conversions may vary from dataset to dataset, a file <dataset>.ini must be placed in each top dataset directory; in this file the necessary programs, which should be in the work directory, must be listed.

2.3 Step-by-step guide to entering a dataset

Entering a new dataset is a straightforward process given the database directory structure described in Section 2.2 and shown in Figure 1:

- At the databank level, a new directory is made with the name <dataset>.
- In the directory <dataset>, various case directories can be made, in each of which the data is stored in the TEKEL-format (Section 2.2.1). Also, a <dataset>.ini must be placed in the directory <dataset>, containing a list of programs for the post-processing of the model output (Section 2.2.3).
In each case directory, model directories are made in which the input file needed to run UNIBEST-TC are put. Also, various files are put here that facilitate (1) the automatic comparison between the model output and the measurements (params.inp, plotdef.inp) and (2) the statistical analysis of the model-data differences (params.ins).
3 Benchmarking datasets: 1. Laboratory measurements

3.1 Overview

In Table 3.1 an overview is given of the implemented laboratory measurements. A description of each data set and of the model-data comparison is provided in Sections 3.3 - 3.8.

Table 3.1 Overview of laboratory data sets and parameters

<table>
<thead>
<tr>
<th>Code</th>
<th>Waves and set-up</th>
<th>Current (2DV)</th>
<th>Current (3D)</th>
<th>Concentrations and transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battjes en Janssen (1978)</td>
<td>BJ78</td>
<td>Hrms</td>
<td>Eta</td>
<td></td>
</tr>
<tr>
<td>Van der Meer (1990)</td>
<td>Meer90</td>
<td>Hrms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stive (1985)</td>
<td>Stive85</td>
<td>Hrms</td>
<td>Eta</td>
<td></td>
</tr>
<tr>
<td>Arcilla et al. (1994)</td>
<td>LIP11D</td>
<td>Hrms</td>
<td>Eta</td>
<td>u(z)</td>
</tr>
<tr>
<td>Reniers et al. (1997)</td>
<td>Reniers</td>
<td>Hrms</td>
<td>Eta</td>
<td>u,v</td>
</tr>
<tr>
<td>Boers (1996)</td>
<td>Boers</td>
<td>Hrms</td>
<td>Eta</td>
<td>u(z)</td>
</tr>
</tbody>
</table>

Hrms = root-mean-square wave height
Eta = set-up/down
u, v = cross-shore and longshore velocity
z = vertical (i.e., vertical profiles are available)
urms = root-mean-square cross-shore velocity
guss = short-wave velocity moment
guls = short-wave long-wave interaction velocity moment
c = sediment concentration
Stotx = total cross-shore sediment transport

3.2 Model set-up

To demonstrate how the database can be used to test different model settings, UNIBEST-TC was run with and without breaker delay (e.g., see Roelvink et al., 1995).

The ‘breaker delay’ concept takes into account the fact that for some condition wave breaking itself only starts some distance shoreward of the point where the waves are obviously ‘tripping over’. It has important morphological consequences such as allowing the growth of breaker bars (Roelvink et al., 1995). However, it has only been tested for its effect on the wave height distribution against a limited set of wave data (mainly LIP11D dataset).
The important model coefficients which determine the behaviour of the wave model are (see also Walstra, 2000):

- **FWEE.** This parameter influences the loss of wave energy due to bottom friction. In cases where the offshore boundary is far from the coast, it has an important influence on the nearshore wave height. In laboratory cases it is unimportant compared to the wave breaking dissipation.

- **GAMMA.** This parameter determines the fraction of breaking waves for a given Hrms wave height and water depth. A smaller value makes waves break earlier than with a large value of gamma. The Battjes and Stive relation for gamma gives an increasing value for decreasing wave steepness.

- **ALFAC.** This determines the rate of dissipation once waves are breaking. In the Battjes and Stive model this is kept at a value of 1.

- **Breaker delay switch K_IJL.** This can be turned on or off.

- **Parameter F_LAM in the breaker delay model (only active when breaker delay is on).** This determines how far back the model looks to determine the depth in the breaker model.

The distribution of the setup relative to the distribution of the wave heights is governed by the roller model. The only user-defined parameter in this model is:

- **BETD,** the representative slope of the breaking wave fronts.

A summary of the standard wave and setup model settings is given in the table below:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FWEE</td>
<td>0.01</td>
</tr>
<tr>
<td>GAMMA</td>
<td>0.0 (i.e., Battjes and Stive, 1985)</td>
</tr>
<tr>
<td>ALFAC</td>
<td>1.0</td>
</tr>
<tr>
<td>K_IJL</td>
<td>1 (ON)</td>
</tr>
<tr>
<td>F_LAM</td>
<td>1.0 (means roughly one wavelength)</td>
</tr>
<tr>
<td>BETD</td>
<td>0.1</td>
</tr>
</tbody>
</table>

### 3.3 Battjes and Janssen (1978)

#### 3.3.1 Dataset description

This dataset was the basis for the first model for random breaking waves (Battjes and Janssen, 1978), which is still widely used and is the basis for the wave model in UNIBEST-TC. The tests were carried out in a wave flume, and contain 8 cases, with varying input wave conditions and both with a plane slope and with a schematized bar.

The parameters measured are the (spectrally determined) Hrms wave height and the setup. Both were measured using resistance-type wave gauges.

#### 3.3.2 Model set-up

As described in Section 3.2.
3.3.3 Results

In fig. 3.3.1 through 3.1.8, the model/data comparisons are given per case, for the standard setting. Obviously, the breaker delay model does not lead to a very good performance: wave heights start to decay too late. This is not surprising since the model was calibrated against these tests without a breaker delay. For comparison results are shown without breaker delay (dashed lines), in which case excellent agreement is found.

3.4 Van der Meer (1990)

3.4.1 Dataset description

The dataset collected by Van der Meer (1990) concerns flume tests of waves breaking on a shallow profile following a step. A notorious aspect of these tests is that the wave decay over the shallow profile tends to be overpredicted by the Battjes and Janssen model. Variables in the different cases are the incident wave parameters and the water level.

3.4.2 Model setup

This is again the same as previous.

3.4.3 Results

Results are shown in Fig. 3.4.1 through 3.4.8. The comparison shows a systematic overprediction of the wave decay and thus an underprediction of wave heights, especially for the cases with a low water level. The breaker delay model tends to postpone the decay a little but leads to an overestimation just after breaking.

3.5 Stive (1985)

3.5.1 Dataset description

Stive (1985) carried out scale comparisons between small scale wave flume results and tests in the large-scale Delta flume. His conclusion was that small-scale results were extremely similar to large-scale results in most aspects of wave breaking. In the test bank we have only included the small-scale results. Two test cases are considered, MS10 and MS40. Characteristics of these tests are an incident Hrms of 0.14 m on a plane 1:40 beach.

3.5.2 Model setup

This is the same as for previous models.
3.5.3 Results

In both tests (Fig. 3.5.1 and 3.5.2) the wave heights in the surfzone are underestimated by the model, and as a consequence, the transition from setdown to setup occurs too early. Inclusion of the breaker delay (drawn lines) improves the predictions slightly.

3.6 Arcilla et al. (1994), Roelvink and Reniers (1995)

3.6.1 Dataset description

Arcilla et al. (1994) conducted a series of comprehensive morphological tests in the large-scale Delta Flume at Delft Hydraulics. Seven tests were carried out in two series. The first series, tests 1a, 1b and 1c, were carried out from an initial Dean-type profile, with a mildly sloping dry beach; the second series was carried out starting from an initial profile with a dune at the waterline but the same underwater profile. Extensive measurements were carried out of wave heights, water levels, flow profiles, wave asymmetry and long waves, concentration profiles and bottom changes. The latter were used to derive total transport rates. Each test lasted 12 to 18 hrs and measurements were carried out throughout every wave hour.

3.6.2 Model setup

In order to reduce the number of cases each test was carried out for one profile somewhere in the middle (near 6 wave hours). Although not all data were collected at the same time this discrepancy was not too severe. Rather than carrying out complete morphological runs the sediment transports derived from the measured bed level changes is compared to the computed total transport rates. This reduces the data set to 7 cases.

The wave model and roller model settings were kept the same as in the previous tests. With respect to the current model, two parameters are important:

- RKVAL, the Nikuradse roughness of the bed.
- FCVISC, a calibration factor in the depth-averaged viscosity, which is related to the wave dissipation by the Battjes (1988) formulation. A lower value leads to more curved cross-shore velocity profiles and to higher longshore velocities. Recommended range is 0.05-0.1.

Values chosen here are:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RKVAL</td>
<td>0.01</td>
</tr>
<tr>
<td>FCVISC</td>
<td>0.05</td>
</tr>
</tbody>
</table>

The sediment transport model requires the following parameters:

- D50, the grain diameter that exceeds 50 % of the grains
- D90, the grain diameter that exceeds 90% of the grains
- DSS, D50 for the suspended material
- RW, the wave-related roughness
- RC, the current-related roughness

Values chosen here are:
3.6.3 Results

The results are shown in Figures 3.6.1 to 3.6.7 for each of the cases. Each figure consists of the following sub-figures:

a) Cross-shore distribution of wave height $H_{rms}$, water level $\eta$, velocity moments $gus$ and $guls$ and total transport.

b) Concentration profiles

c) Velocity profiles.

In all cases computations were carried out with (drawn lines) and without breaker delay (dashed lines).

Wave heights

Generally, good agreement is found for the cross-shore distribution of $H_{rms}$. In the cases 1c and 2c, both of which are for low, long waves, including the breaker delay gives much improvement in the bar and trough region.

Setup

Very good qualitative and quantitative agreement is found for all tests.

Guss

The general shape of the cross-shore distribution of the short wave velocity moment $gus$, related to vertical wave asymmetry, is predicted reasonably well. However, in all cases the model overpredicts the values. This is especially the case in the inner surf zone.

Guls

The model predicts the values of the long wave – short wave interaction moment $GULS$ reasonably well for tests 1a, 1b, 2a and 2b. This is not entirely surprising, since it was derived and calibrated in Roelvink and Stive based on similar test conditions. However, for the low-steepness cases 1c and 2c, the model predictions are far too high; measured values are an order of magnitude lower.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>D50</td>
<td>200 $\mu$m</td>
</tr>
<tr>
<td>D90</td>
<td>300 $\mu$m</td>
</tr>
<tr>
<td>DSS</td>
<td>170 $\mu$m</td>
</tr>
<tr>
<td>RW</td>
<td>0.002</td>
</tr>
<tr>
<td>RC</td>
<td>0.01</td>
</tr>
</tbody>
</table>
**Sediment concentrations**

The computed sediment concentrations generally agree with the measured values to a reasonable extent. The shapes of the concentration profiles are similar to the measured ones. Bottom concentrations are generally within a factor of 2 to 3 of the measurements.

**Velocity profiles**

The computed velocity profiles are generally in agreement with the measured ones, except for the region around the bar, where they are quite sensitive to the details of the driving forces related to wave dissipation. Here also the effect of including breaker delay is shown clearly.

**Total sediment transport**

The general shape of the cross-shore distribution of the cross-shore transport is similar in computations (thick line) and model. However, quantitative agreement is poor with the model exceeding the computations by an order of magnitude.

3.7 Reniers et al. (1997)

3.7.1 Dataset description

This dataset refers to experiments in the multi-directional wave basin at Delft Hydraulics, aimed at the study of shear instabilities of the longshore current. For this purpose, a barred beach was constructed at an angle of 30 degrees with respect to the wave paddles. The wave-generated longshore current was recirculated using a pump system and a careful layout of the inflow and outflow sections, resulting in quite uniform mean flow conditions. Most of the tests were carried out with regular waves, except for case SO014, which was done with random, unidirectional waves. Since UNIBEST-TC can only model random waves this case was included in the testbank.

3.7.2 Model set-up

The wave and roller model settings were identical to the previous tests. The chosen current model parameters were:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RKVAL</td>
<td>0.0005</td>
</tr>
<tr>
<td>FCVISC</td>
<td>0.05</td>
</tr>
</tbody>
</table>

3.7.3 Results

The rms wave height was reproduced accurately by the model (Fig. 3.7.1). The effect of the breaker delay on the cross-shore evolution of the wave height and set-up is small, although both are predicted slightly better without breaker delay (dashed line). The agreement between modeled and measured longshore current is good in a qualitative sense (e.g.,
maximum in longshore current is at the proper location), but the current is generally underpredicted by about 30 - 50 %.

3.8  Boers (1996)

3.8.1  Dataset description

This is an extremely detailed, high-quality set of hydrodynamic data in a wave flume at Delft University. This fixed-bed dataset is a reproduction of the mobile-bed dataset of LIP11D, allowing much more detailed study of the hydrodynamic parameters. Only a selection of the full dataset has been chosen for comparison with UNIBEST-TC:
- Hrms wave height
- Eta, wave setup
- Vertical profiles of the time-averaged horizontal velocity

3.8.2  Model set-up

With respect to the wave and setup models, the same parameters are used as in the Battjes and Janssen tests. With respect to the current model, the following parameter values were used:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RKVAL</td>
<td>0.001</td>
</tr>
<tr>
<td>FCVISC</td>
<td>0.05</td>
</tr>
</tbody>
</table>

3.8.3  Results

Results are shown in Figures 3.8.1 through 3.8.3. Per figure the subfigures a) show wave height Hrms and setup Eta, while subfigures b) show all measured and computed velocity profiles.

**Wave heights**

The wave heights are generally predicted quite accurately. As in the LIP11D experiments, the breaker delay model gives a major improvement for test 1c; for the other tests results without breaker delay are slightly better.

**Setup**

The setup distribution is predicted very well, especially when breaker delay is included.

**Velocity profiles**

In the majority of cases the velocity profiles below the wave trough level are predicted quite accurately, both qualitatively and quantitatively. Around the pronounced bar the biggest discrepancies occur.
4 Benchmarking data sets: 2. Field measurements

4.1 Overview

An overview of the implemented field data sets is provided in Table 4.1.

Table 4.1 Overview of laboratory data sets and parameters

<table>
<thead>
<tr>
<th>Code</th>
<th>Waves and set-up</th>
<th>Current (2DV)</th>
<th>Current (3D)</th>
<th>Concentrations and transport</th>
<th>Bottom change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hotta and Mizuguchi (1980)</td>
<td>Hotmiz</td>
<td>Hrms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ebersole and Hughes (1987)</td>
<td>Duck85</td>
<td>Hrms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coast3D</td>
<td>Egmond Hyd</td>
<td>Hrms</td>
<td>u,v</td>
<td>urms</td>
<td>guss, guls</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>c(z)</td>
<td>z(x,t)</td>
</tr>
<tr>
<td>Egmond Morph</td>
<td>Egmond Long</td>
<td></td>
<td></td>
<td>z(x,t)</td>
<td></td>
</tr>
</tbody>
</table>

Hrms = root-mean-square wave height
u, v = cross-shore and longshore velocity
(z) = vertical (i.e., vertical profiles are available)
z(x,t) = cross-shore bottom profiles (various moments in time)
urms = root-mean-square cross-shore velocity
guss = short-wave velocity moment
guls = short-wave long-wave interaction velocity moment
c = sediment concentration

4.2 Hotta and Mizuguchi (1980)

4.2.1 Dataset description

Hotta and Mizuguchi (1980) carried out detailed measurements of various wave statistics across a barred surfzone using the photopole technique. In this technique a number of poles were put in a row across the surfzone. The waves passing the poles were filmed, and the elevation along each pole was digitised and converted to a time series, which could then be analysed. Hotta and Mizuguchi report various wave parameters; the parameter selected here is the rms wave height.
4.2.2 Model setup

The parameter settings were taken identical to the Battjes and Janssen (1978) case.

4.2.3 Results

The measured and computed wave heights are shown in Fig. 4.2.1, with and without breaker delay, respectively. In this case, with relatively long waves, the run with breaker delay shows significantly better results.

4.3 Ebersole and Hughes (1987)

4.3.1 Dataset description

The Duck85 experiment took place at the Field Research Facility near Duck, NC. The technique used was similar to the photopole technique used by Hotta and Mizuguchi. Various statistics of the long Atlantic waves breaking over a bar were recorded. Again, we use the spectrally defined Hrms wave heights for comparison with UNIBEST-TC.

4.3.2 Model setup

The same model settings were used as in previous sections. Since only the shallow water profile was given, the model starts at a relatively shallow depth. However, no breaking occurs at the boundary.

4.3.3 Results

The measurements show a very strong shoaling over the bar (Figures 4.3.1 - 4.3.9), to a high wave height over water depth ratio. As was pointed out by Dally (1990), there was a strong offshore wind during some conditions, which delayed the point of breaking. This is not represented in the model. However, with these swell conditions on the relatively steep bar, wave breaking does not start instantaneously and the breaker delay concept is clearly applicable.

4.4 Egmond Hydrodynamic

4.4.1 Data set description

The Egmond site is located in the central part of the Dutch North Sea coast and is dominated by two well-developed shore-parallel bars intersected by rip channels. In the framework of the Coast3D project, two field campaigns were executed, a pilot campaign in spring 1998 and a main campaign in autumn 1998. During the experiments, a large variety
of instruments, such as pressure sensors, wave buoys and current meters, were deployed. An overview can be found in Appendix I and in Ruessink (1999). Contrary to the pilot campaign, the main experiment witnessed severe conditions. Large waves, strong wind and water level rises due to storm surges were present, resulting in considerable morphologic change (e.g. bar movement, lowering of bar crests and the presence of rip channels).

Two Coast3D data sets were added to the database: Egmond Hydrodynamic and Egmond Morphodynamic. For both data sets, four cases were defined: pre-storm, storm, post storm, and total period. Egmond Morphodynamic is described in Section 4.5.

### 4.4.2 Cases and model set-up

#### Cases

For the reproduction of the hydrodynamics at Egmond during the Egmond Main measurement campaign we have chosen the following cases:

<table>
<thead>
<tr>
<th>Burst Nr.</th>
<th>Date-time</th>
<th>Days in UNIBEST-TC</th>
<th>Tot. days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-storm</td>
<td>9180-9324</td>
<td>18-10-98 12:00 - 24-10-98 12:00</td>
<td>382.5 - 388.5</td>
</tr>
<tr>
<td>Storm</td>
<td>9324-9492</td>
<td>24-10-98 12:00 - 31-10-98 12:00</td>
<td>388.5 - 395.5</td>
</tr>
<tr>
<td>Post-storm</td>
<td>9492-9780</td>
<td>31-10-98 12:00 - 12-11-98 12:00</td>
<td>395.5 - 407.5</td>
</tr>
<tr>
<td>Total period</td>
<td>9180-9780</td>
<td>18-10-98 12:00 - 12-11-98 12:00</td>
<td>382.5 - 407.5</td>
</tr>
</tbody>
</table>

The burstnumbers are based on conventions regarding measurement administration in the COAST3D project. Burst numbers can be linked with actual dates and times. Burst number 9180 corresponds with noon 18 October 1998 and each burst is valid one hour exactly (e.g. burst number 9181 corresponds with 13:00, 18 October 1998). To facilitate comparison of model results and measurements we have chosen burst number 0 as the starting time of the modelling exercise. Consequently, burstnumbers divided by 24, yield the corresponding input for our UNIBEST-TC model. For the geographical orientation we have chosen to take the offshore DIWAR buoy as the origin for the modelling exercise with the positive x-axis to be in the shoreward direction (see Figure 4.1). Positive y is directed alongshore in northward direction.

The cases of the hydrodynamic dataset include the following parameters: Hrms, Uxmean, Uymean, Guss and Guls. For Hrms, Uxmean, Uymean, Guss and Guls we include measurements from stations 7a, 2, 1a, 1b, 1c and 1d. The measurement stations are located at the following positions (see also Figure 4.1):
For these parameters we include measured profiles and timeseries. The timeseries are given at the measurement locations measured from DIWAR and are named HrmsXxxxx.tek, UxmeanXxxxx.tek, UymeanXxxxx.tek, GussXxxxx.tek and GulsXxxxx.tek, respectively. The profiles include the data from the measurement locations at a large number of time points evenly distributed over the case periods. The profiles are named HrmsTtttt.tek, UxmeanTtttt.tek, UymeanTtttt.tek, GussTtttt.tek and GulsTtttt.tek.

**Model set-up**

For the testing of the models hydrodynamic capabilities we use the non-averaged bathymetry data from the main array. Each case starts with the actual bathymetry at that moment, derived from the measurements. During Egmond Main the bathymetry has been measured at regular intervals. The model automatically updates the bathymetry from this data after each day of calculation. The necessity to feed UNIBEST with new bathymetries *during* the calculations required UNIBEST-TC to be modified.

**Input file**

The UNIBEST-TC input file is standardised for all reference cases. Most entries are the same for all cases; entries related to the number of time steps and the starting time of each case obviously differ (the size of the time step was chosen 1 hour in all cases):

<table>
<thead>
<tr>
<th>Case</th>
<th>Time step [days]</th>
<th>Nr. of timesteps</th>
<th>Starting time [days]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-storm</td>
<td>0.041666667</td>
<td>144</td>
<td>382.5</td>
</tr>
<tr>
<td>Storm</td>
<td>0.041666667</td>
<td>160</td>
<td>388.5</td>
</tr>
<tr>
<td>Post-storm</td>
<td>0.041666667</td>
<td>288</td>
<td>395.5</td>
</tr>
<tr>
<td>Total period</td>
<td>0.041666667</td>
<td>600</td>
<td>382.5</td>
</tr>
</tbody>
</table>

Other varying entries are considering the output of profiles and timeseries.
Parameter settings

We use the following parameters settings:

- **DT’**: 0.041666667 Time step [days]
- **N’**: 600 Number of timesteps [ - ]
- **IBOD’**: 0 Morphodynamic switch [0 = no / 1 = yes]
- **TIME_ST’**: 382.5 Starting time [days]
- **TDRY’**: 25 Relative wave period [-]
- **K_IJL’**: 1 Breaker delay switch [-]
- **F_LAM’**: 2.000000 Number of wave lengths over which weighted depth is integrated [-]
- **POW’**: 1.000000 Power in weighting function [-]
- **K_IJL’**: 1 Breaker delay switch [-]
- **DEEP_V’**: 3500.000000 Seaward boundary [m] of zone along which \( \lambda \) is reduced by factor \( \sin^2 \Theta \)
- **SHALL_V’**: 5000.000000 Landward boundary [m] of zone along which \( \lambda \) is reduced by factor \( \sin^2 \Theta \)
- **GAMMA’**: 0.000000 Wavebreaking parameter for use in dissipation formulation according to Battjes & Janssen (1978)
- **FWEE’**: 0.010000 Friction factor for wave dissipation due to bottom friction. The default value FWEE = 0.01 is obtained from Delta Flume experiments.
- **TCVISC’**: 0.100000 Viscosity coefficient \( \alpha_w \) of vertical velocity profile
- **RKVAL’**: 0.050000 Friction factor for mean current computation. The default value is RKVAL = 0.01
- **DIEPV’**: 15.790000 Reference depth for tidal velocity
- **DTBOT’**: 1 Bottom update related parameter
- **END’**: 0.000000 Bottom update related parameter

Boundary conditions

The dynamic boundary conditions for the UNIBEST-TC runs have been included in separate files. The following hydrodynamic and meteorological parameters have been entered into the model as boundary condition files:

- Tidal elevation [m] TideTotalperiod.ubc
- Tidal velocity [m/s] TidevTotalperiod.ubc
- Wave angle [Deg] WaveThTotalperiod.ubc
- Wave height (RMS) [m] WaveHTotalperiod.ubc
- Peak wave period [s] WindTotalperiod.ubc
- Wind velocity [m/s] WaveTpTotalperiod.ubc
- Wind direction [Deg] WaveTpTotalperiod.ubc

The files contain the conditions for the Totalperiod-case in particular, but the other cases use the same files. The other cases cover parts of the interval spanned by the Totalperiod-case. The boundary conditions for these cases are obtained by pointing at the relevant time intervals in these boundary condition files. As bottom boundary conditions we included:

- Bottom profile [m] Bot4all.bot
- Fixed layer [m] -30.0 m

4.4.3 Results

Interpretation Hrms timeseries

The figure illustrating the Hrms timeseries consists of six graphs (Fig. 4.4.2). From HrmsX4460 to HrmsX4818, in the direction of the shore, they show the development in time of the rms waveheight. In onshore direction we see a growing influence of the tides in
the measured as well as the computed wave signal. Measurements shown in HrmsX4460 and HrmsX4485 are located on the seaward side of the outer bar. The other measurement locations are located on both sides of the inner bar (see Figure 4.4.1). The waveheights are systematically overestimated by UNIBEST-TC for all locations but especially the four located around the inner bar. Dissipation is underestimated. A likely explanation for this underestimation is the choice for the value of gamma. In this particular UNIBEST model we set the gamma value on zero, the default value turning on the Battjes-Stive approach for the automatic calculation of the gamma value. A lower gamma value would lead to earlier wave breaking and thus more dissipation. On shore winds could also lead to earlier breaking of waves. It might be necessary to include the role of wind force and direction in the calculation of the gamma value.

**Interpretation Uxmean timeseries**

The measurements and the model results are poorly correlated (Fig. 4.4.3). To check the influence of the averaging applied in the Uxmean parameter we investigated the behaviour of the U10 parameter. This parameter calculates the nonaveraged cross shore velocity 10 cm above the bed. The results did not improve. The differences between measurements and model results are consistent with the notion that the cross shore velocities can not be explained from cross shore processes alone (cf. Elias et al., 2000).

**Interpretation Uymean timeseries**

The calculated Uymean correlates much better with the measurements (Fig. 4.4.4). Although the patterns in the longshore currents are well predicted the size is systematically underestimated. We expect this discrepancy to be caused by an equally systematic overestimation of the bottom friction. The statistical parameters RBIAS, SI, RBIAS1 and OPI show very high values indicating a much worse model performance than is expected from the plots. The reason for this is that the Uymean signal of both measurements and calculations varies around zero. This causes division by a very small number, blowing up the statistical parameters.

**Interpretation Guss timeseries**

The assymmetry of the shorter waves is grossly overestimated by UNIBEST-TC for all measurement locations except for the most offshore measurement station gussX4485 (Fig. 4.4.5). The applied approach of Rienecker and Fenton (1981) is especially valid on deeper water where wave breaking is less. Once waves start breaking it appears that wave assymetry is significantly reduced. The approach by Rienecker and Fenton does not include this change, explaining the mismatch between measurements and model results. Another approach by Isobe and Horikawa is currently under investigation and is expected to give better results.

**Interpretation Guls timeseries**

Similar to the Guss results, the measured Guls are strongly overpredicted by the model (Fig. 4.4.6). The model switches the Guls sign from - to + when the wave energy in the boundary
condition is reduced by 50%. When the model results are compared to the measurements this sign reversal happens too early.

**Interpretation Hrms profiles**

When looking at the Hrms profiles (Fig. 4.4.7) we come to the same conclusions as in the Hrms timeseries. Looking at HrmsT9285 for example we can see that breaking starts too late and stops too early. The reason can again be found in the overestimation of the gamma value. Again the wind direction may have some influence on the value of gamma. Wind from behind will accelerate breaking whereas an offshore wind direction will delay the breaking of the waves. Such an influence is not implemented in the currently used formulations for the calculation of gamma. The averaged statistics for all profiles results in a BIAS of 0.189 and a RMS value of 0.212 indicating an averaged error of about 20 cm. From the timeseries we can see this error is mainly caused by the four station around the inner bar. This means that the RMS error in Hrms waveheight in these points is probably order 30% higher than 20 cm.

**Interpretation Uxmean profiles**

The Uxmean profiles (Fig. 4.4.8) confirms the conclusions drawn from the timeseries. It seems however that the model does predict some of the peaks, although their location seems to be predicted a little seaward.

**Interpretation Uymean profiles**

From the timeseries we found the model to follow the patterns in the longshore velocities reasonably well (Fig. 4.4.9). However, cross-shore profile look rather strange, with stronger flows in the offshore and trough areas. This is likely due to the way tidal currents are estimated from the most seaward measurement point. Occasionally, this position is well within the surfzone. The corresponding wave-driven flow is then incorrectly considered to be tide-induced and results in a strong overestimation of the alongshore surface slope that drives the tidal current.

### 4.5 Egmond Morphodynamic

#### 4.5.1 Cases

For the reproduction of the morfodynamics at Egmond during the Egmond Main measurement campaign we have chosen the same cases as for the hydrodynamics.

#### 4.5.2 Measurements

The bottom profiles for each case have been included.
4.5.3 Reference model

UNIBEST-TC version

In the morphologic test case we use the same hydrodynamic and meteorological boundary conditions as in the hydrodynamic test case. For the morphologic testcases however we no longer update the bathymetry because we are now interested in the models capability to predict the morphological behaviour under the given boundary conditions. As initial bathymetry we now take an averaged profile ‘to accommodate the longshore uniformity assumption’ implemented in UNIBEST-TC. We will compare the morphological evolution predicted by UNIBEST-TC with the evolution of the averaged measured profiles.

Input file

The same cases as for the hydrodynamics have been applied for the testing of the morphology.

Parameter settings

The input parameter IBOD is set to ‘1’ turning on the morphologic change. Because updating the bottom profile is no longer relevant the parameter DTBOT has been removed.

Boundary conditions

The dynamic boundary conditions for the UNIBEST-TC runs have been included in separate files. The same hydrodynamic and meteorological parameters have been entered into the model as in the hydrodynamic test case. The files again contain the conditions for the Totalperiod-case in particular, but the other cases use the same files. As bottom boundary condition we now include:

<table>
<thead>
<tr>
<th>Bottom profile [m]</th>
<th>Fixed layer [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botavall.bot</td>
<td>-30.0 m</td>
</tr>
</tbody>
</table>

4.5.4 Results

Results are shown in Figure 4.5.1. In the lower plot, the thick line is the measured, alongshore averaged profile at the end of the Coast3D campaign, whereas the thin line is the prediction. Although the overall direction of bar migration is predicted correctly (both bars are observed and predicted to move offshore), the predicted shape of the bar doesn’t resemble the measurements. The outer bar has moved offshore too far, and has also been lowered too much. The inner trough has largely disappeared in the predictions, partly due to erosion of the beach and partly due to infilling with sand from the inner bar. The latter is likely caused by the overprediction of the onshore transport (guss) over the bar, see Section 4.4.
4.6 EgmondLong

4.6.1 Dataset description

This dataset consists of yearly profile measurements near Egmond, profile 39.500, over a period of 18 years from 1979 to 1997, and associated boundary conditions. A full description can be found in Boers and Walstra (1999).

4.6.2 Model setup

The model setup is fully described by Boers and Walstra (1999), their Appendix B.1.

4.6.3 Results

Measured (dots) and modeled (lines) profiles are presented in Figure 4.6.1. From 1979 to 1987, the outer bar is predicted to migrate farther offshore than in the measurements. In 1987, the difference in position between the predicted and measured outer bar crest is about 100 m. Afterwards, the outer bar vanishes from the measured profiles, but in the model results the outer bar remains visible until 1993. Afterwards, the shape of the predicted new outer bar/trough becomes rather unrealistic, with a narrow pronounced bar and a wide (200 m) trough. The inner nearshore, at depths less than about 3 m, is predicted to accrete strongly which causes an almost complete disappearance of the inner bar. This accretion is, however, not observed in the measured profiles, causing a mismatch in the mean water line (0 m) of almost 200 m. Boers and Walstra (1999) note that variations of the model parameters had little impact on the accretion of the beach.
5 Statistical analysis

In the previous two chapters, model performance was largely judged visually, resulting in the qualitative and subjective terms ‘poor’, ‘reasonable’ and ‘excellent’. This is often sufficient during early stages of a project (e.g., parts of the calibration phase), but usually quantitative Model Performance Statistics (MPS), computed based on a direct comparison between model results and measurements, are needed. MPS values can be computed with the newly designed Statistical Analysis Tool (SAT), described by Walstra (2000), and shortly introduced in the following.

5.1 Tool

A shell (see Figure) has been constructed which enables an efficient use of the database. With the shell it is possible to set-up a sequence of UNIBEST-TC runs and the subsequent statistical analysis and visualisation. Furthermore, the SAT results of various model runs can be compared, saved for later use and visualised. In the model directory the Statistical Analysis Tool (SAT) can be used to investigate the model performance for the required parameters. The SAT interpolates the calculated values to the measurement locations or time points and performs a number of statistical operations and saves the results to file.

Figure 5.1 SAT-shell of benchmarking database for UNIBEST-TC

With the [BROWSE] button the user has to select the parent directory which is displayed in the status bar at the bottom of the window. In the top left list box a listing is given of the directories in the parent directory. With the “active directory” the user can specify the working directory. With the “select parameter” list box the user can select an output parameter from which the statistical error ranges are collected.
If the selection is made according to Figure 1, pressing [COMPARE] will result in a search of the highlighted directories within the active directory (1a, 1c, 2b, and 2e) for a directory “v2” with MPS’s concerning the selected parameter (HRMS). The results of the search are printed in the “results” window. As can be seen in Figure 2, the results window also displays an average over all the MPS’s that have been found. By pressing [SAVE] these results can be stored in ASCII-file. Note that multiple searches (e.g. for HRMS and ETA) can be stored in one output file. The [RESET] button will empty the search buffer. With the [VISUALISE] button below the results window the MPS’s can be visualised in bar charts.

The [BATCH] button creates batch files to run UNIBEST-TC in the “v2” directory residing under the selected directories (1a, 1c, 2b, and 2e). The UNIBEST-TC batch file (extension btc) should be loaded into Batch-TC from which UNIBEST-TC can be run in batch. Also a normal batch file is created which arranges the data extraction, statistical error analysis and visualisation with MATLAB. Note that in this case the “parameter selection” is not used.

The [PARAMETER] button creates a batch file to modify the parameter settings in the input for UNIBEST-TC in the “v2” directory residing under the selected directories (1a, 1c, 2b, and 2e). In the work directory a file called “key.inp” is present which can be edited. All the settings in the selected UNIBEST-TC input files will be overwritten according to the settings in the “key.inp” file.

### 5.2 Model Performance Statistics

The following table presents an overview of the MPSs implemented in SAT and their interpretation.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bias</td>
<td>systematic error</td>
<td>can become negative, low values indicate low systematic error</td>
</tr>
<tr>
<td>RMS</td>
<td>standard deviation of the error</td>
<td>low values indicate low systematic error</td>
</tr>
<tr>
<td>Rel. Bias</td>
<td>systematic error rel. to the mean</td>
<td>low values indicate a good model performance (relative low values for the mean can cause high values)</td>
</tr>
<tr>
<td>Scatter Index (SI)</td>
<td>standard deviation rel. to the mean</td>
<td>low values indicate a good model performance (relative low values for the mean can cause high values)</td>
</tr>
<tr>
<td>Bias/$f_{\text{meas},i}$</td>
<td>systematic error rel. to the start or boundary value</td>
<td>values tend to be low due to high offshore values</td>
</tr>
<tr>
<td>Operational Performance Index (OPI)</td>
<td>standard deviation rel. to the start or boundary value</td>
<td>values tend to be low due to high offshore values</td>
</tr>
<tr>
<td>Model Performance Index (MPI)</td>
<td>is defined in terms of rms differences and rms changes</td>
<td>for perfect model MPI=1</td>
</tr>
<tr>
<td>Brier Skill Index (BSI)</td>
<td>mean squared differences between measured values, modelled values and a set of baseline predictions.</td>
<td>can be used to evaluate improved versions by using predictions of original model as baseline predictions</td>
</tr>
</tbody>
</table>

### 5.3 Examples

In this section we present two examples of SAT use based on the Testbank:

- **Optical Performance Index (OPI)** for Hrms values, where $OPI$ is defined by

\[
OPI = \frac{1}{N-1} \sum_{i=2}^{N} \frac{(f_{\text{comp},i} - f_{\text{meas},i})^2}{f_{\text{meas},1}}
\]

(the subscript 1 in the denominator refers to the seaward boundary value)

and

- **Relative Bias ($RBIAS$)** for Guss, where $RBIAS$ is
Figure 5.1 shows the OPI values for a total of 39 cases. OPI values are shown both for the model runs with breaker delay (‘Series 1’, light columns) and without breaker delay (‘Series 2’, dark columns). In several cases, as also described in Chapter 3, inclusion of the breaker delay improves model predictions. For instance, for the Duck85 data OPI reduces between 30 to 50%. In other cases, results with and without breaker delay are almost identical (data boers) or predictions are better without breaker delay (data Battjes and Janssen). On average, OPI is 0.08, with implies that the standard deviation of the difference between modeled and measured Hrms is about 8% of the offshore Hrms.

\[
RBIAS = \frac{\sum_{i=1}^{N} (f_{\text{comp},i} - f_{\text{meas},i})}{\sum_{i=1}^{N} f_{\text{meas},i}}
\]

Figure 5.2 presents relative biases for Guss of the LIP IID data set. Again, \( RBIAS \) was computed for runs with breaker delay (‘v1’, light columns) and without breaker delay (‘v2’, dark columns). In all cases, \( RBIAS \) is positive, which implies that the model overpredicts the measurements (as is visually clear from Fig. 3.6.1a to 3.6.7a). In all cases, differences between predictions with and without breaker delay are small. On average, \( RBIAS \) is about 0.75 for the runs with breaker delay, implying that on average Guss is overpredicted by 75%. Without breaker delay, the average overprediction reduced to about 55% (\( RBIAS \) approximately 0.55).
Fig. 5.2 Relative bias for Guss in the LIP IID dataset.
6 Benchmarking database for Delft3D-MOR

6.1 Introduction

Delft3D-MOR is a subset of the Delft3D modelling system, which is designed to simulate wave propagation, currents, sediment transport, morphological developments and water aspects in coastal, river and estuarine areas (Roelvink and Van Banning, 1994). Delft3D-MOR can be applied to coastal areas including beaches, channels, sand bars, harbour moles, offshore breakwaters, groins and other structures. In addition, it is applicable to estuaries, tidal inlets, river deltas influenced by tidal currents and river discharges and possibly characterized by the presence of tidal flats, channels and man-made structures like jetties and land reclamations.

As Delft3D-MOR consists of four separate modules (WAVE, FLOW, TRAN and BOTT) ideally a benchmark database would consists of four subsets against which each of the modules can be tested. However, this lies not in the scope of the present study. Here the aim is to identify and characterise a limited number of datasets which can be used to evaluate Delft3D-MOR as a complete system. Some benchmarking databases are already available for the individual sub-modules (e.g. there is an extensive benchmarking database available for SWAN, which is part of Delft3D-WAVE). Recently, the Coast3D-project has provided detailed field data for Egmond and Teignmouth (UK) which can be used to evaluate Delft3D-MOR.

6.2 Coast3D-data

The data obtained from field campaigns carried out within the framework of the Coast3D-project in Egmond and Teignmouth will be included in the benchmarking database. Furthermore, the Delft3D-models that have been set-up (e.g. grids, bathymetries, boundary conditions, etc.) will be collected as well. The available data will be stored and organised according to the data structure of the benchmarking database of UNIBEST-TC. The following datasets have been added to the database:

- Coast3D - Pilot Campaign at Egmond,
- Coast3D - Pilot Campaign at Teignmouth.

6.3 Inventory of other datasets

Within WL|Delft Hydraulics many data sets are used for benchmark testing when upgrading Delft3D-MOR. These datasets are available but have not formally been combined and described. Within the limited scope of this sub-project the following datasets have also been added to the benchmarking database:

- LIP11D - Tests 1A en 1B (Delta Flume),
- Reniers - Test SO014 (Test in Vinje basin).
7 Conclusions and Recommendations

7.1 Summary

A benchmarking database has been implemented with the objective to facilitate testing of various model settings. The database has been sub-divided into separate datasets, in which a number of cases are defined (Figure 2.2.1). This structure implies that running a simple script file in a case directory automatically runs the model and produces plots that compare the model output with available measurements at predefined moments and places. The clear database structure allows a user to straightforwardly insert a new dataset. Up to now, 11 data sets have been implemented, as described in Chapter 3 and 4. The data sets include both laboratory and field measurements. The majority of the datasets have been selected for their applicability to enable the testing of various hydrodynamic physical processes, such as wave height, and cross-shore and longshore velocity. Various other also include sediment transport information and profile development. Besides comparison of model results and experiments, the benchmarking database facilitates statistical error analysis. As such, the differences between model predictions and measurements are quantified, allowing to compare the model performance on different datasets, different cases and even different model runs.

7.2 Reference model performance

For the purpose of this work, standard UNIBEST-TC has been run on all datasets implemented in the database. The following tentative conclusions can be drawn:

- the cross-shore evolution of the wave height Hrms is reproduced reasonably accurately by the model, with a database average Optical Performance Index of 0.08. In some cases (e.g., Egmond) wave heights in a bar trough are overestimated, implying insufficient dissipation across the bar.
- in the laboratory, mean cross-shore Uxmean and longshore Uymean velocity are modeled reasonably well. For Uxmean, differences are largest near the bar crest and above the wave trough (which is not included in UNIBEST). In the field, agreement between measured and modeled Uxmean is poor (Coast3D, EgmondHyd). Measured and modeled Uymean show good qualitative agreement, but measured Uymean is typically 30-50% underpredicted.
- values of Guls and Guss are systematically overpredicted by the model, both in the field and in the laboratory.
- long-term predictions of nearshore morphology (EgmondLong) appear reasonable for a few years, but afterwards differences between measured and modeled morphology become increasingly large. Especially the predicted continuous accretion of the beach appears unrealistic.
7.3 Recommendations

7.3.1 UNIBEST-TC

The final results of UNIBEST-TC are the computed longshore sediment transport and the predicted profile development. These result from the predictions of the underlying hydrodynamics and sediment transport. The comparison in Chapters 3 and 4 imply that improvements are needed for:

- **wave height prediction.** On average, the cross-shore evolution of the wave height is reproduced reasonably accurately, with an average OPI value of 0.08. However, inner surf zone heights appear to be systematically overpredicted by the model. This points to a re-evaluation of the gamma breaker parameter, either by a new offshore parameterisation or by a cross-shore varying parameterisation. Also the effect of breaker delay needs to be investigated more systematically.

- **cross-shore and longshore currents.** Modeled and measured cross-shore currents in the field are poorly related. More work is needed to establish whether this is related to the present model formulations and/or to the violation of alongshore uniformity under field conditions (rip currents). The longshore currents are systematically underpredicted, which requires additional work on the bottom stress parameterisation. Also, the alongshore surface slope prediction should be improved. If the reference position is chosen too close to the shore (as in EgmondHydr), unrealistically large tidal currents result.

- **sediment transport.** Guss is systematically overpredicted by the model, perhaps related to the use of a wave theory that cannot be used under strong breaking waves in shallow water. The results of another method (Isobe and Horikawa) to predict Guss is recommended. Also, the effect of wave breaking on asymmetry needs to be clarified.

- **morphology.** It needs to be established more clearly from field data to what extent observed bar changes are alongshore uniform or not. In the latter case, alongshore averaging of profiles may be suitable way to proceed, but this should be confirmed from more data sets.

The following recommendations are made for the UNIBEST-TC database:

- inclusion of more hydrodynamical data sets, especially obtained under field conditions. Examples are the Nourtec and the Petten data set.

- inclusion of more morphological data sets, consisting of cross-shore profiles over a wide range of time scales (days to years). Preferably, the profiles are longshore averaged to remove longshore morphological non-uniformities. Also, the dune erosion data set of Steetzel should be included.

- inclusion of data sets of longshore sediment transport rates.

- a more complete analysis of model-data differences using SAT.
7.3.2 Delft3D-MOR

At present the benchmarking database for Delft3D has the same datastructure as the UNIBEST-TC database. However, implementation of standard postprocessing and statistical error-analysis lies outside the scope of this project. Based on our (limited) experience with the UNIBEST-TC database we suggest that the Delft3D database will remain to have the same datastructure. Furthermore, many of the tools that were developed for the UNIBEST-TC database (e.g. the SAT-shell, Statistical Analysis Tool itself and visualisation) are generic and can also be used for the Delft3D database.

The following recommendations are made to upgrade the Delft3D database to the level of UNIBEST-TC database:

- Construction of batch-files to run Delft3D from SAT-shell,
- Construction of VS (viewer-selector) scripts to automate data-extraction,
- Construction of Delft3D model for relevant datasets of the UNIBEST-TC database (e.g. Boers, and Duck95),
- Description of the Delft3D benchmark tests, according to the format of the UNIBEST-TC descriptions.


8 References


Boers, M., 1996. Simulation of a surfzone with a barred beach; Report 1: wave heights and wave breaking. Communications on Hydraulic and Geotechnical Engineering, Delft University of Technology, the Netherlands.


Appendix I: Egmond Coast3D

Measurements and instrumentation

Data collected concerned:

- Waves: spectrum of wave height, period and direction, near bed orbital velocities, breaker type, fraction of breaking waves;
- Water Levels: tidal levels, storm surges, wave set-up;
- Currents: depth averaged currents, velocity profile;
- Water properties: salinity and temperature, density structures;
- Sediment properties: grain size distribution, settling velocity and density;
- Sediment transport: transport mode, rates and directions, concentration profiles;
- Morphology: bed levels before and after events, changes along cross-shore and longshore transects, cross- and longshore movement of large bed features such as nearshore breaker bars.

A range of instruments was deployed on site to perform these measurements:

**WESP**

The WESP (Water En Strand Profiler) is a 15 m high, motorised tripod on wheels with a platform at the top supporting engine and a cabin with facilities. Survey was conducted from the beach out to water depths of 8 m. It is valuable for collection of sand transport data and will be used for measuring the 3-dimensional bathymetry of the near shore zone. In this study the bathymetry data collected with the WESP is used.

The WESP made lanes with a spacing of 50 m in the longshore direction. Depending on the wave conditions measurements were made to a maximum depth of approximately 7 m. Bathymetry data obtained by a ship and measured on the beach was added to the WESP data in order to obtain a complete bottom profile.

**CRIS**

CRIS is a trailer towed by the WESP, carrying various instruments for measuring sediment transport, water levels, wave parameters and flow velocities. It also takes measurements of the sand concentration profiles. The CRIS is 3.5 meters squared and 2.5 meters high. The instruments are attached to a movable arm, which can be adjusted in vertical direction to position the sensors at the desired elevation above the bed.

**DIWAR**

The DIWAR (Directional Wave Rider) buoy is located outside the Egmond area in (almost) deep water. It collects the wave data (height, period, direction). Data used were root-mean-square wave height ($H_{rms}$), peak period ($T_p$) and direction ($\theta$). Gaps in DIWAR data were filled with measurements from other DIWAR buoys, located at the ‘IJmuiden munitie-stortplaats’ and the ‘Europlatform’.
Measuring poles (7a-7f)
In total six poles were operating during the measurement campaigns. A number of local variables and boundary conditions are measured. For example, water level and meteorological data is collected, the wind velocity and direction measured at this pole were used in this report. The poles also form a physical barrier for ships and mark and protect the measurement site.

Maxi frames (2 and 1a-d)
The maxi frames measure several parameters. The data used in this study are wave heights, water levels and current velocities. The maxi frames are positioned in the so-called main transect in the area of interest. A fictive cross-section (normal to the shore-line) at the location of the maxi frames was defined as the main transect.

S4-instruments (18a-d, 13a-b, 14a-b, 15)
S4-instruments are current and pressure meters. Station 18a and station 18b are located in deeper water (seaward flank of outer bar), station 18c and station 18d are located in the surf zone. Data from station 18a and station 18b was used to estimate the deep water (at DIWAR location) tidal longshore currents. Station 14a and station 13a are located at the crest of the inner bar, station 14b and station 13b are located at the landward flank of the inner bar, near the inner channel.

Only a small selection of the data produced in the main campaign is used in this report. For our model performance check we only use bathymetry data and hydrodynamic data from measuring pole 7a and maxiframes 2 and 1a-d.
Appendix II: Figures
Dataset bj78 – test BJ11
Cross-shore distribution

Unibest–TC
Run v1

WL | DELFT HYDRAULICS

Fig. 3.1.1
Dataset bj78 – test BJ12
Cross–shore distribution

Unibest–TC Run v1

WL I DELFT HYDRAULICS

Fig. 3.1.2
Dataset bj78 – test BJ13
Cross-shore distribution

ETA

HRMS

WL | DELFT HYDRAULICS

Unibest–TC Run v1

Fig. 3.1.3
Dataset bj78 – test BJ14
Cross–shore distribution

Unibest–TC Run v1

WL | DELFT HYDRAULICS

Fig. 3.1.4
Dataset bj78 – test BJ15
Cross–shore distribution

Unibest–TC
Run v1

WL I DELFT HYDRAULICS

Fig. 3.1.5
Dataset bj78 – test BJ2
Cross-shore distribution

Fig. 3.1.6
Fig. 3.1.7

Cross-shore distribution

Dataset bj78 – test BJ3

Unibest–TC Run v1

WL | DELFT HYDRAULICS

Fig. 3.1.7
Cross−shore distribution

Dataset bj78 − test BJ4

Cross−shore distribution

WL | DELFT HYDRAULICS

Unibest−TC  Run v1

Fig. 3.1.8
Dataset duck85 – test D41400
Cross-shore distribution
Dataset duck85 – test D41510
Cross–shore distribution

Unibest–TC Run v1

WL | DELFT HYDRAULICS

Fig. 3.3.2
Dataset duck85 – test D50955
Cross-shore distribution

Unibest–TC  Run v1

WL I DELFT HYDRAULICS

Fig. 3.3.3
Dataset duck85 – test D51055
Cross-shore distribution

Fig. 3.3.4
Dataset duck85 – test D51352
Cross–shore distribution

WL | DELFT HYDRAULICS
Dataset duck85 – test D51525
Cross-shore distribution

WL | DELFT HYDRAULICS
Dataset duck85 – test D60915
Cross-shore distribution

Unibest–TC  Run v1

WL | DELFT HYDRAULICS

Fig. 3.3.7
Dataset duck85 – test D61015
Cross–shore distribution

Fig. 3.3.8

WL | DELFT HYDRAULICS

Unibest–TC Run v1

Fig. 3.3.8
Dataset duck85 – test D61300
Cross-shore distribution

Fig. 3.3.9
Cross-shore distribution

Dataset meer90 – test TST007

WL | DELFT HYDRAULICS

Fig. 3.4.1
Dataset meer90 – test TST110
Cross-shore distribution

Unibest-TC
Run v1

WL I DELFT HYDRAULICS

Fig. 3.4.3
Dataset meer90 – test TST13
Cross–shore distribution

Fig. 3.4.5

Unibest–TC
Run v1

WL | DELFT HYDRAULICS

Fig. 3.4.5
Dataset meer90 – test TST216
Cross-shore distribution

Figure 3.4.7
Cross-shore distribution

Fig. 3.4.8
Dataset stive85 – test MS10
Cross–shore distribution

Fig. 3.5.1
Dataset lip11d – test 1a
Concentration profiles

Unibest–TC
Run v1

WL | DELFT HYDRAULICS

Fig. 3.6.1b
Dataset lip11d – test 1a
Return flow profiles

Unibest–TC Run v1

Fig. 3.6.1c
Dataset lip11d – test 1b
Cross–shore distribution

Unibest–TC Run v1

WL I DELFT HYDRAULICS

Fig. 3.6.2a
Fig. 3.6.2b

Dataset lip11d - test 1b
Concentration profiles

Unibest-TC
Run v1

WL | DELFT HYDRAULICS

Fig. 3.6.2b
Dataset lip11d – test 1b
Return flow profiles

Unibest–TC Run v1

WL | DELFT HYDRAULICS

Fig. 3.6.2c
Dataset lip11d − test 1a
Cross−shore distribution

Unibest−TC
Run v1

WL | DELFT HYDRAULICS

Fig. 3.6.1a
Dataset lip11d − test 1c
Concentration profiles

Fig. 3.6.3b
Dataset lip11d – test 1c
Return flow profiles

WL | DELFT HYDRAULICS

Fig. 3.6.3c
Fig. 3.6.4b

Dataset lip11d – test 2a
Concentration profiles

Unibest–TC  Run v1

WL | DELFT HYDRAULICS

Fig. 3.6.4b
Fig. 3.6.4c

Dataset lip11d – test 2a
Return flow profiles

Unibest–TC Run v1

WL | DELFT HYDRAULICS

Fig. 3.6.4c
Dataset lip11d – test 2b
Concentration profiles

Unibest–TC  Run v1

Fig. 3.6.5b
Dataset lip11d – test 2c
Cross–shore distribution

Unibest–TC Run v1

WL I DELFT HYDRAULICS

Fig. 3.6.6a
Dataset lip11d – test 2c
Return flow profiles

Unibest–TC  Run v1

Fig. 3.6.6c
Fig. 3.6.7a

Dataset lip11d – test 2e
Cross–shore distribution

Unibest–TC Run v1
Fig. 3.6.7c

Dataset lip11d – test 2e
Return flow profiles

Unibest–TC
Run v1

WL | DELFT HYDRAULICS

Fig. 3.6.7c
Cross-shore distribution

Dataset reniers – test sO014
Unibest–TC Run v1

Fig. 3.7.1
Dataset boers – test 1a
Cross–shore distribution

Figure A

Unibest–TC
Run v1

WL I DELFT HYDRAULICS

Fig. A
Dataset boers – test 1b
Cross-shore distribution

HRMS

ETA

WL | DELFT HYDRAULICS

Unibest-TC | Run v1

Fig. 3.8.2a
Dataset boers – test 1b
Velocity profiles

Unibest–TC  Run v1

WL | DELFT HYDRAULICS

Fig. 3.8.2b
Fig. 3.8.3b
Dataset duck85 – test D41400
Cross-shore distribution

Unibest–TC
Run v1

WL | DELFT HYDRAULICS

Fig. 4.3.1
Dataset duck85 – test D51055
Cross-shore distribution
Dataset duck85 – test D51352
Cross-shore distribution

Unibest-TC | Run v1

WL | DELFT HYDRAULICS

Fig. 4.3.5
Dataset duck85 – test D61015
Cross-shore distribution

WL | DELFT HYDRAULICS
Dataset EgmondHydr – test Totalperiod
Hrms wave height

Fig. 4.4.2
Dataset EgmondHydr – test Total period
Cross-shore velocity

Unibest-TC
Run V1

WL | DELFT HYDRAULICS

Fig. 4.4.3
Dataset EgmondHydr – test Totalperiod
Wave asymmetry (long)

Unibest–TC  Run V1

WL I DELFT HYDRAULICS

Fig. 4.4.6
Dataset EgmondHydr – test Totalperiod
Hrms wave height III

Unibest–TC
Run V1

WL I DELFT HYDRAULICS

Fig. 4.4.7c
Dataset Egmond-Hydr – test Totalperiod
Cross-shore velocity II

WL I Delft Hydraulics

Unibest-TC  Run V1

Fig. 4.4.8b
Dataset EgmondHydr – test Totalperiod
Longshore velocity I

WL | DELFT HYDRAULICS

<table>
<thead>
<tr>
<th>Unibest–TC</th>
<th>Run V1</th>
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<tbody>
<tr>
<td></td>
<td>Fig. 4.4.9a</td>
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</table>
Dataset EgmondLong – test egm395
Profile evolution

WL I DELFT HYDRAULICS

Fig. 4.6.1
WL | Delft Hydraulics

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