Modeling of Hurricane Impacts

Interim Report 7
January-May 2008

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Contents

Abstract

This interim report describes activities in the second quarter of the second year of the project 'Modeling of Hurricane Impacts'. In agreement with the funding agency, the work was carried out over the period August-December 2007. Three main lines of work are described in this report, viz. dissemination of model and results, model improvements and testing.

1 Introduction

This report is the sixth interim report of the project 'Modeling of Hurricane Impacts', contract no. N62558-06-C-2006, which was granted by the US Army Corps of Engineers, Engineer Research and Development Center (ERDC), European Research Office and administered by FISC SIGONELLA, NAVAL REGIONAL CONTRACTING DET LONDON, SHORE/FLEET TEAM. This report covers the activities over the period of January 1st, 2008 until June 1st, 2008, funded under item 1003. The reporting period has been extended to accommodate delays in funding for the forthcoming items.

The project is being carried out by Prof. Dano Roelvink of UNESCO-IHE (Principal Investigator), Dr. Ad Reniers (Delft University and University of Miami), Jaap van Thiel de Vries and Robert McCall of Delft University of Technology and Dr. Ap van Dongeren and Jamie Lescinski of WL | Delft Hydraulics.

The various activities over the period of January-June 2008 are outlined in Chapter 2. In Chapter 3 we outline plans for the coming period.

2 Activities March-August 2006

2.1 Dissemination of XBeach

Maintenance and use of website www.xbeach.org

The XBeach website has been a useful means of disseminating the code and helping each other out in getting the code running and discussing problems. The number of members is now approximately 40 from a wide range of institutes worldwide.

Presentation of results on conferences and workshops

A well-attended presentation was given by Dano Roelvink at Ocean Sciences 2008 (Orlando). An abstract was accepted for ICCE 2008 (Hamburg).

Testing at ERDC

Mark Gravens and Ty Wamsley at ERDC are starting to validate XBeach against the full set of test cases for SBEACH. Collaboration between CHL and USGS at St Petersburg will likely speed up the introduction of XBeach to CHL.

Collaboration with ECORS group, France

A group of French universities led by the University of Bordeaux, plus several ones from UK, Australia and the US have carried out a very large field experiment on the Atlantic coast of France in March 2008. In this project, sponsored by the French navy, XBeach will be applied, with help of our group, to model swash motions and resulting morphological changes on the beach. Several members of the group have obtained beta versions. Ad Reniers joined the experiment for the whole period, while Dano Roelvink and students visited the experiments in the first week of March (both with funding from elsewhere)

Collaboration with USGS

The USGS at St Petersburg, Fl (Abby Sallenger and David Thompson) have actively worked on the modelling of barrier island overwashing, aided by Jaap van Thiel de Vries and Robert McCall, who visited St Pete for two resp. eight weeks. The results are summarised below.

The USGS in St Petersburg (Florida) has gathered an enormous data set with lidar of pre -and post hurricane bathymetries and topographies (Sallenger, 2005). Within the co-op between WL|Delft Hydarulics and USGS, an Xbeach model has been set up with pre hurricane Ivan measurements at Santa Rosa Island located in front of the North Western Florida coast (see figure 1). The model covers one kilometer in alongshore direction and about 1.7 kilometers in cross shore direction. The grid size is uniform in long shore direction (Δy = 20m) and variable in cross shore direction changing with the water depth. The minimum grid size (Δx) is found in shallow water / dry areas and is 2 meter. Surge, wave height, wave period and wave direction vary during the simulation.

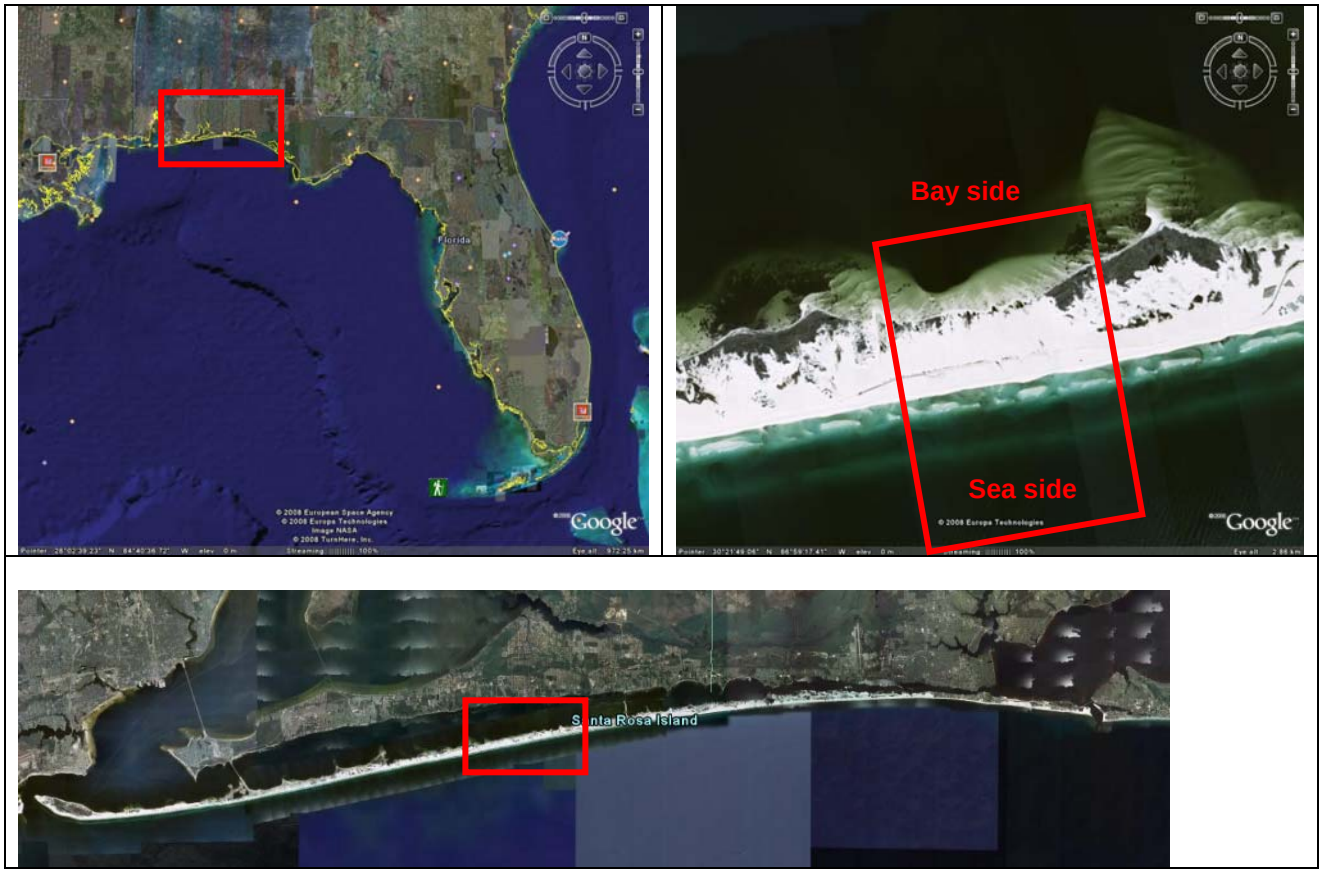


Figure1: Location of Santa Rosa Island and the modeled area (upper right image). All images are post Ivan and you can clearly see the overwash vans in the upper right panel.

Several adaptations have been made to the XBeach source code in order to improve the model performance. The most important improvements are:

- A new time step criterion has been implemented following Stelling (1984):

$$C = 2\Delta t\sqrt{gh\left(\frac{1}{\Delta x^2}+\frac{1}{\Delta y^2}\right)}$$

- The weakly reflective boundary condition (Van Dongeren and Svendsen, 1997) that is used at the offshore boundary is also implemented at the bay side boundary

- The convective terms in the NSWE ($v\frac{\partial u}{\partial y}$ and $u\frac{\partial v}{\partial x}$) are rewritten into a momentum conservative numerical scheme (Stelling and Duinmeijer 2003) in order to correctly model the evolution of shock waves.

Three snap shots of the XBeach simulation are shown below and show respectively dune erosion, initial overwash and the peak of the hurricane. In the central panel we see bathymetry and water surface elevations (including wave group generated long waves). Bed level changes are projected on the white surface below (red is erosion and green is sedimentation, see color bar on the left). The lower left panel shows the surge level (the red line indicates the actual time) and the lower right panel shows wave direction (green line) and wave height (blue line).

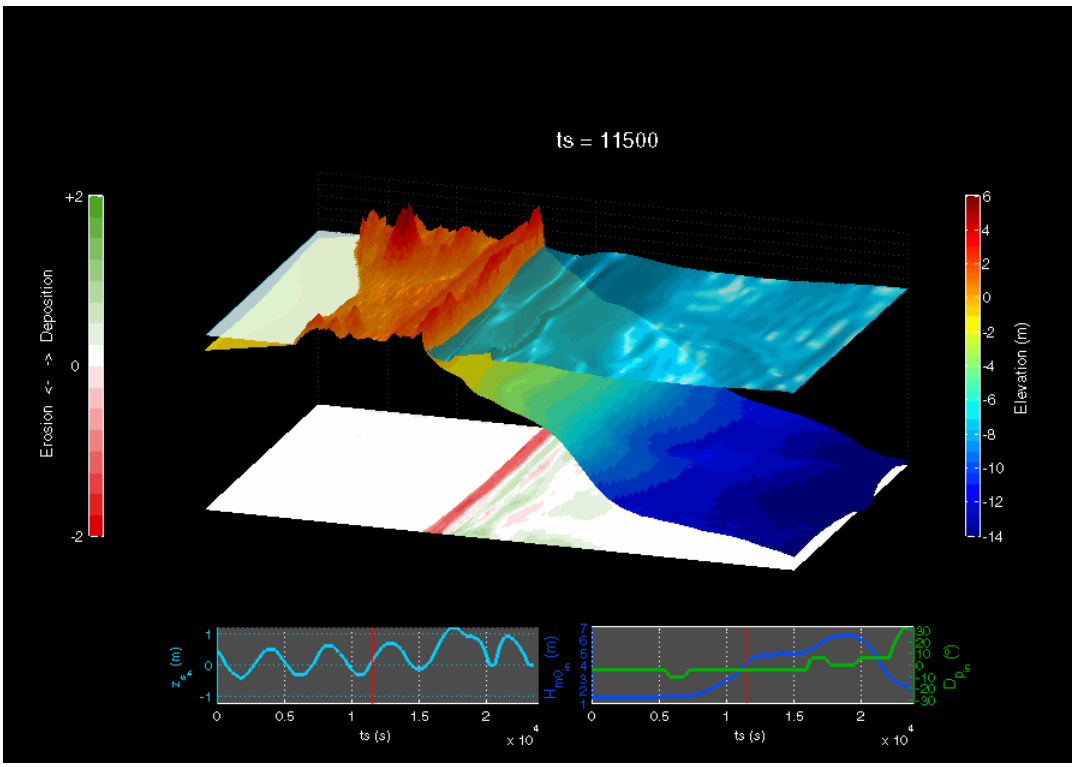


Figure 2a: At the start of hurricane Ivan, when the surge is not that high yet, large storm waves cause dune erosion.

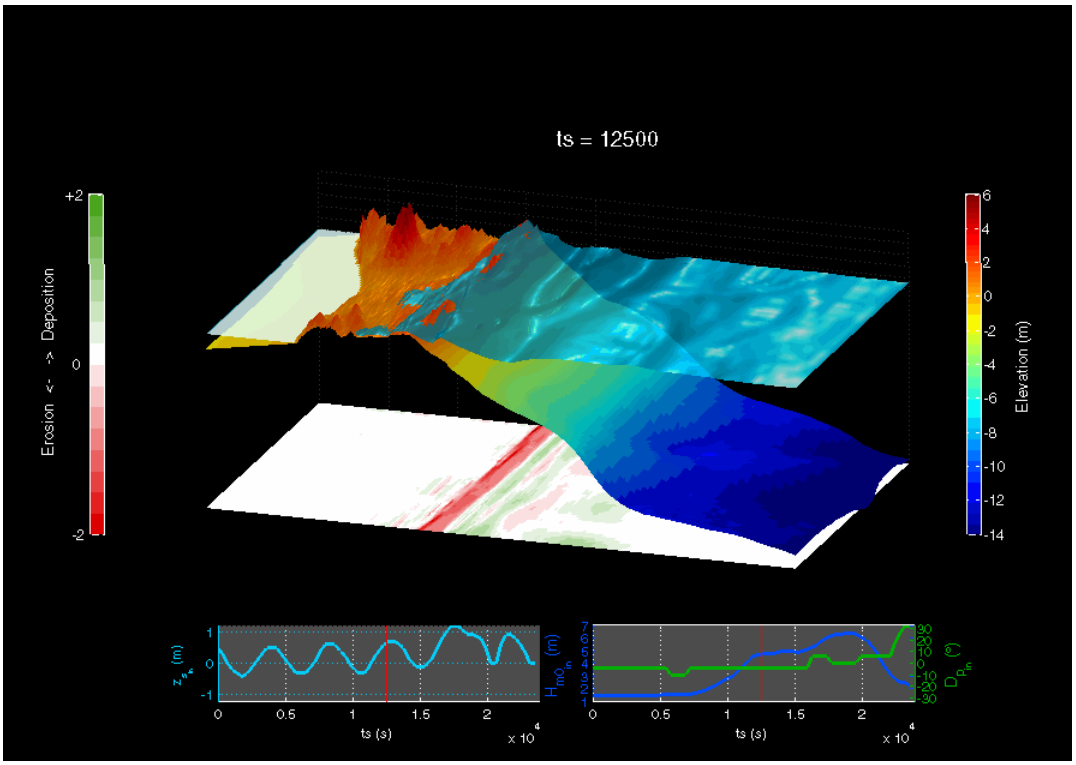


Figure 2b: Due to the increasing water level and dune erosion Santa Rosa Island is overwashed. The overwash volume is still limited and is related to the long wave run-up. The mean water level is still below the dune crest.

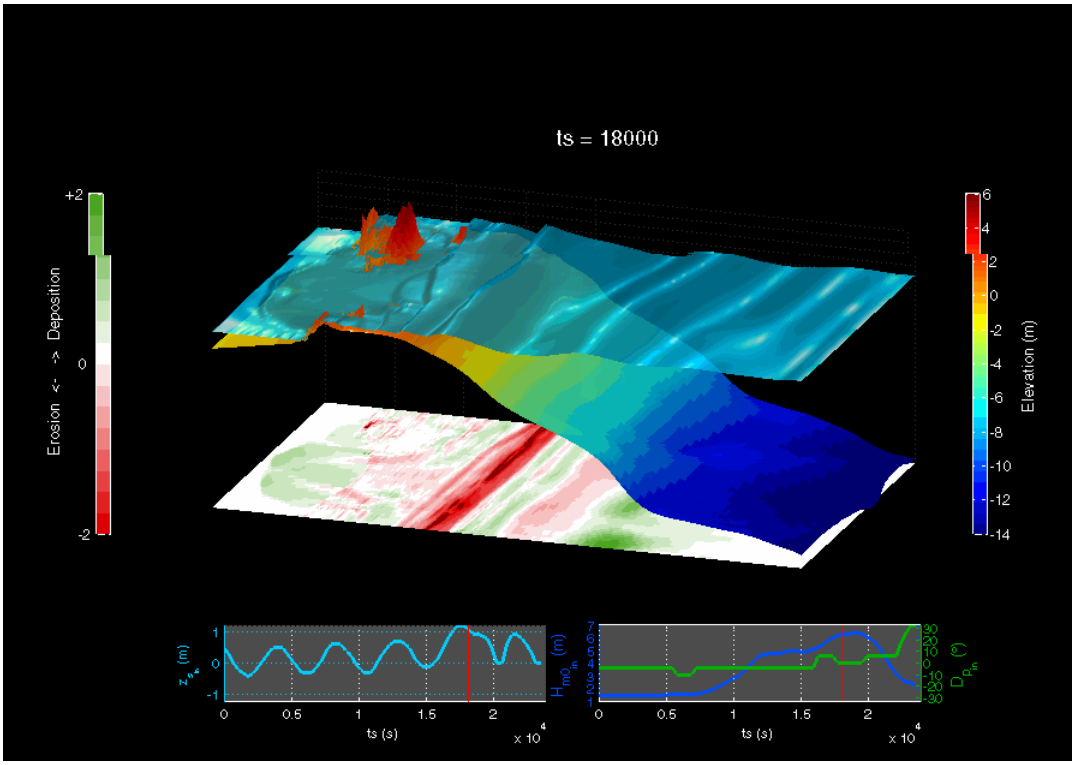


Figure 2c: At the peak of the storm full overwash takes place (the mean water level is above the elevation of the barrier) and a lot of sand is washed over the island. An 'overwash van' develops as is also observed in the lidar measurements and obtained post storm images. First impression is that XBeach slightly overestimates the wash over of sediment which is probably related to the incorrect simulation of water levels at the bay side, which are kept constant in the present simulations and must have fluctuated when the hurricane passed.

Sallenger, A. H., C. W. Wright, and J. Lillycrop (2005), Coastal impacts of the 2004 hurricanes measured with airborne lidar; initial results, *Shore and Beach*, *73*, 10-14.

Stelling, G. S. (1984), On the construction of computational methods for shallow water flow problems, Rijkswaterstaat Commun., The Hague, Netherlands.

Stelling, G. S., and S. P. A. Duinmeijer (2003), A staggered conservative scheme for every Froude number in rapidly varied shallow water flows, *International journal for numerical methods in fluids*, *43*, 1329-1354.

Van Dongeren, A. R., and I. A. Svendsen (1997), Absorbing-generating boundary condition for shallow water models, *Journal of waterway, port, coastal and ocean engineering*, 303-313.

Incorporation in EU FP7 project

XBeach has been proposed as central model in a large EU 7th Framework Programme project, MICORE, about storm impacts on European coasts. Several members of this team will work with XBeach within that project, which now has got EU approval and will start on June 1st, 2008. Most members of our team will participate in this.

Collaboration with NOPP-CSTM project

The XBeach model has been presented to the NOPP – Community Sediment Transport Model project during the last May workshop in Woods Hole and at the Ocean Sciences Meeting. Concepts from XBeach may be implemented into the ROMS-SED environment, whereas XBeach can profit from experiences in that group.

Collaboration with individual researchers

This list has become quite extensive; on xbeach.org the members can be viewed.

Papers in preparation

Dano Roelvink, Ad Reniers, Ap van Dongeren, Jaap van Thiel de Vries, Jamie Lescinski, Dirk-Jan Walstra. Modelling of coastal processes under storm conditions, to be submitted to Coastal Engineering.

2.2 Implementation under LINUX and parallelization

The final platform-specific statements were removed from the code, thereby making it identical under Windows and Linux.

With support by Willem Vermin of the Dutch national computer center SARA we have started to parallelize the code using automatic domain decomposition and MPI. A first working version has been produced and is still in the process op being optimized.

2.3 Implementation of water level gradients on lateral boundaries

For cases where the water level at both seaward corner points are different, the water level gradient between these points is imposed at both lateral boundaries. This allows the longshore current to be driven by alongshore gradients, e.g. in the case of tides propagating along a shallow coast or alongshore propagating storm surges.

2.4 Free long waves on boundary

Apart from the option of sending in bound long waves along with the short wave energy variations, the user can now also just send in free long waves. This was tested with theoretical runup cases based on Carrier and Greenspan (1959) and Zelt (...).

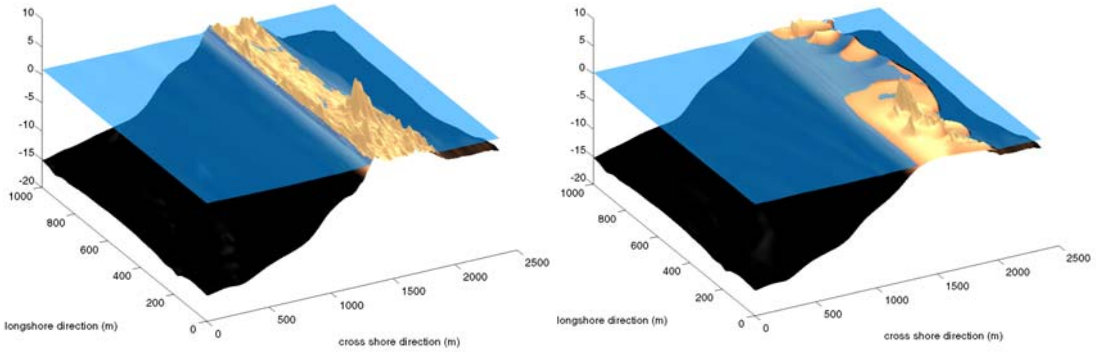
2.5 Implementation of non-uniform gridsize

The numerical method has been extended to allow non-uniform gridsizes in x and y direction, though the restriction to rectilinear grids remains. The user can now specify input files with x, y and bottom level, in the same format as the existing file for bottom level. Extensive tests have been carried out to verify the correct implementation. These will be reported in a separate report. In the latest version the grid can either be specified in computational x and y values plus orientation and origin of the grid, or in world coordinates, in which case the computational x and y values are derived from the world z and y coordinates.

2.6 Validation tests on 2D behaviour

In the framework of his MSc study at Delft Hydraulics Robert McCall carried out an extensive series of tests focusing on the 2D behaviour of XBeach, culminating in a real-life case of overwashing of Santa Rosa Island. The report will be made available through the xbeach.org website.

Pre-storm Post-storm



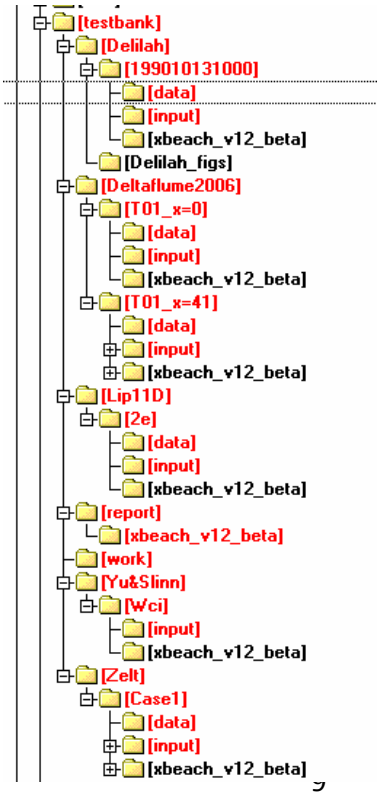
Ref.
Robert McCall, 2008. The longshore dimension in dune overwash modelling. Development, verification and validation of XBeach. MSc thesis TU Delft, May, 2008.

2.7 Setup of a validation test bed

A first version of an automated test bed was set up, in order to facilitate comparison between XBeach and analytical or measured data and to quickly check if a new version has not regressed in functionality. The test bed consists of a directory structure containing datasets and cases within these datasets; for each case there is

- an input directory which contains the input files for XBeach and postprocessing matlab scripts, of which the topmost has to be called plotdata.m
- a data directory where the data to compare model results against resides.

From a directory *work* all cases are run through using the script *runall.m* and all postprocessing is done using the script *plotall.m*. Resulting plots are collected in the directory

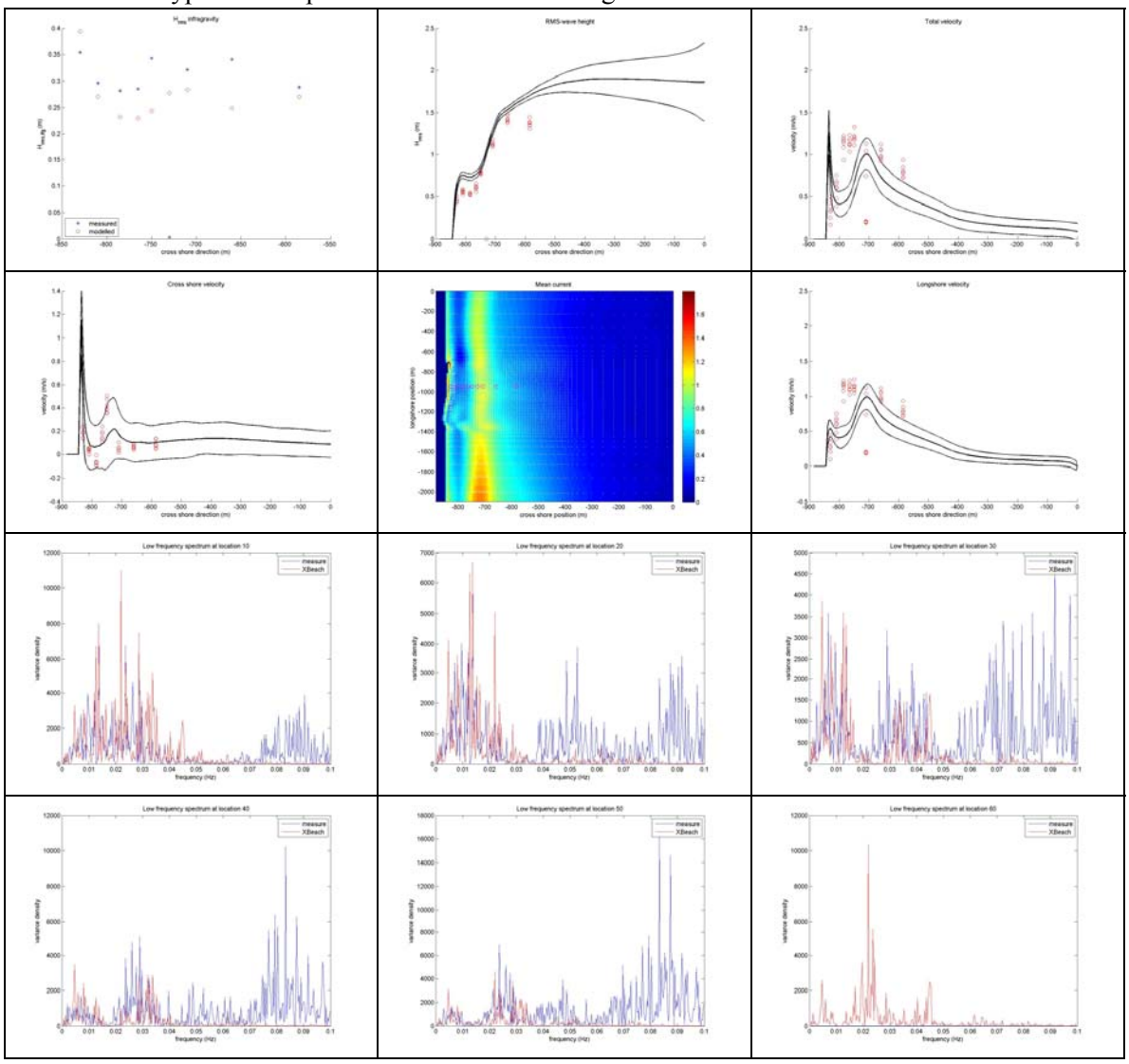


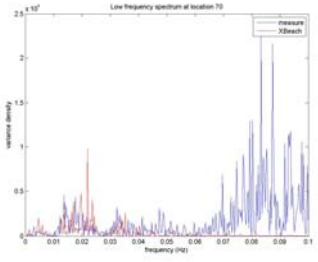
report\<*runid*>, where <*runid*> refers to the version used. So far the following tests have been included:

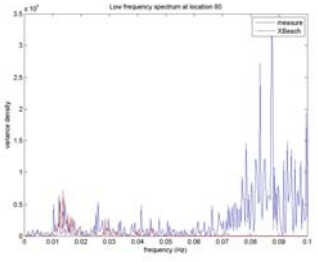
- Delilah, one test of hydrodynamics only with comparisons for wave heights, spectra and velocities
- Deltaflume2006, a dune erosion case with detailed hydrodynamic measurements
- LIP11D, a dune erosion case with a barred profile
- YuSlinn, a test of wave-current interaction on a rip geometry
- Zelt, a 2D non-uniform runup case

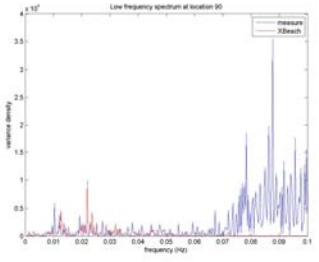
The present state of the test bed is that of a prototype. It has already been used to test the latest version on the web, xbeach_v12_beta. Much can and will be done to make the procedures more uniform and robust, to output quantitative measures of error and to give quantitative measures of differences with the previous version.

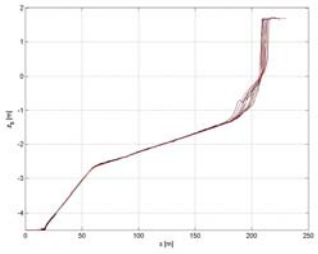
Below some typical examples of test bed results are given.

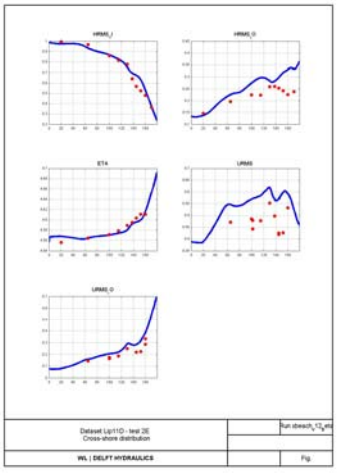


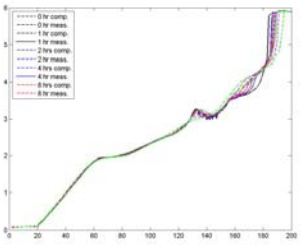

Low frequency spectrum at location 70
measure
XBeach
variance density
frequency (Hz)

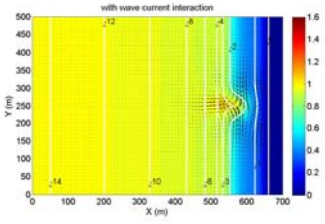

Low frequency spectrum at location 80
measure
XBeach
variance density
frequency (Hz)


Low frequency spectrum at location 90
measure
XBeach
variance density
frequency (Hz)


x [m]


Dataset Lip11D - test 2E
Cross-shore distribution
WL | DELFT HYDRAULICS
Fig.


0 hr comp.
0 hr meas.
1 hr comp.
1 hr meas.
2 hrs comp.
2 hr meas.
4 hrs comp.
4 hr meas.
6 hrs comp.
6 hr meas.


with wave current interaction
Y (m)
X (m)

3 Plans for coming period

For the coming period we plan the following activities:

- Adding different optional sediment transport formulations
- Adding non-hydrostatic wave model
- Adding quasi-3D modelling of return flow and wave skewness and asymmetry effects
- Preparation of journal paper manuscripts
- Preparation of an updated user manual
- Further testing wave-current interaction in present release
- Assisting in testing by ERDC, especially for the SBEACH test suite.
- Implementation of parallel version into mainstream version
- Testing against Oregon State Univ. dune overwash tests
- Testing against data for Monterey Bay, in collaboration with Univ. of Miami and Naval Postgraduate School
- Testing against Truc Vert data (France)
- Further testing against field data on hurricane impacts
- Participating in workshop end of August