

# **Prediction of Medium-scale Morphodynamics – PROMORPH**

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## **Abstract**

This paper deals with medium scale morphodynamics at the German North Sea coast. The future work of this project, so called PROMORPH, as well as first results will be shown. The important part of measurement campaigns and the already developed database to ensure the data exchange will be presented. Furthermore the work on the development of the models and their coupling will be shown. Finally some results of the qualitative morphodynamic modelling are described.

## **1. Introduction**

The management of coastal areas relies increasingly on predictions carried out by numerical models. Yet such models have rarely been tested adequately against field measurements. The objective of this project is to develop, calibrate and validate numerical models to simulate morphological changes over periods of several years. The domain of investigation is a tidal flat region in the German Wadden Sea. Model calibration and validation is being conducted with extensive field measurements of waves, water levels, velocities, sediment transport and morphology. Deterministic and stochastic approaches for simulating changes in the morphology over longer periods are being employed.

## **2. Participation**

The following institutes and research centers are involved in the joint project PROMORPH.

1. Institute of Fluid Mechanics at Hannover University, Hannover
2. Coastal Research Laboratory at the Research and Technology Center West Coast in Büsum of the University of Kiel, Kiel
3. Institute of Meteorology and Climatology at Hannover University, Hannover
4. GKSS Research Centre, Geesthacht

The Office for Rural Development in Husum and the Federal Maritime and Hydrographic Agency in Hamburg also contribute to the project.

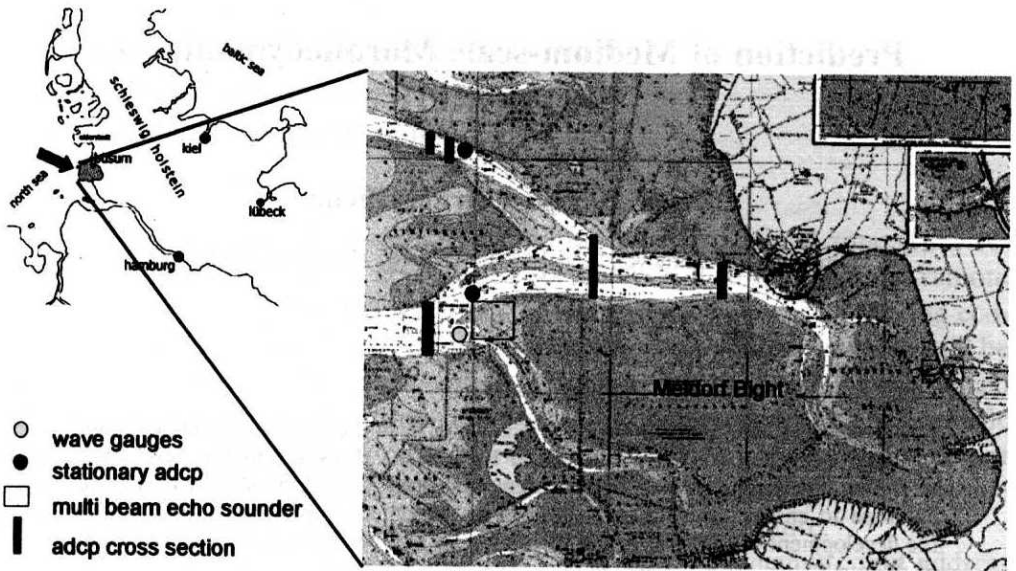


Fig. 1. Location of the area of examination and some measurement areas

### 3. Study Area

The domain of investigation (about 600 km<sup>2</sup>) is the Meldorf Bight, on the German Wadden Sea. The study area can be easily accessed making measurement campaigns more effective. The morphology of the domain with intertidal flats (50% of the area) and channels is controlled by the combined effect of tides, wind-driven currents and wind waves. The main channel of the tidal basin has a maximum depth of about 20 m. Tidal range is around 3.5 m; sediments are mostly sandy and partly muddy.

### 4. Field Measurements

Waves, water levels, currents, water properties, sediment properties, sediment transport as bed load and in suspension, morphology and meteorology are being measured at defined locations, transects and throughout morphologically relevant areas. Measurement campaigns at regular time intervals (every few months) and after relevant events like storms as well as continuous monitoring of meteorology, water levels and velocities (two stationary ADCP) are being carried out. Research vessels equipped with modern measuring instruments are used simultaneously to cover a larger area and thus provide the information necessary to more adequately

validate the models. Gauges, buoys, pressure sensors, ship-mounted and stationary Acoustic Doppler Current Profilers (ADCP), single beam as well as multi-beam echo sounders, side-scan sonar, a variety of sediment and water samplers are used to measure hydrodynamics, sediment transport, sea bed characteristics and sediment distribution. Special attention will be given to bed load measurements using highly advanced hydroacoustic methods and to the investigation of morphological changes based on multi-beam echo sounders data.

## 5. Data Management

In order to ensure a good exchange of data between the project partners a webbased Meta-Database is designed. This database contains an input-tool, based on Java language, to enable the project partners to put the Meta-Data into the base by themselves. They can generate a description and a header by filling out a form for each dataset, they want to distribute to the public. Because the data themselves are still on the computers of the project partners, they can decide whether they want to secure them using a password or not. The database is accessible under <http://www.hydromech.uni-hannover.de/PROMORPH>.

## 6. Modelling

A large-scale model covering the North West continental shelf area (CSM) is used to generate water level boundary conditions for the model of the German Bight (GBM). The GBM generates boundary conditions (water levels) for the model of the Meldorf Bight (s. Fig. 2).

The modelling activities have been divided into two phases. In the first one, model developments, calibration and validation using measurements of water levels, waves, currents, sediment transport and morphology for short-term events are being carried out. The calibration and validation will be done at defined locations and transections within the investigation area, and focussing towards morphologically relevant regions. In the second phase, after successful calibration and validation for short-term events, deterministic and stochastic approaches for simulating changes in the morphology over periods of up to 5 years will be considered. The results of both approaches will be calibrated and validated using long term measurements of morphology and compared against each other. Predictions of morphological evolutions will be carried out for relevant scenarios.

### 6.1. Model Validation

The model validation is done using different measurements to the calibration phase. For the validation the September 1990 is used, because of the low wind phase in the first half of the month and the storm event in the second half of the

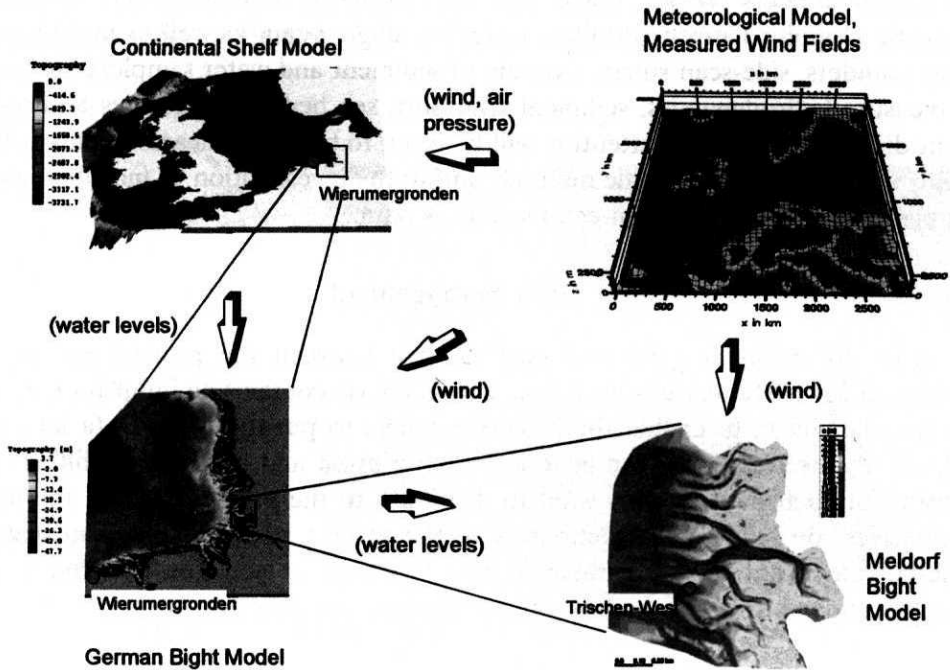


Fig. 2. Model Coupling

month. For the greater model CSM a gauge (Wierumergronden s. Fig. 2) near the boundary of the next smaller model (GBM) is shown in figure 3.

The RMS-error for this example was around 15 cm which is not too bad. The boundary conditions for the CSM are generated out of six astronomical tides: M2, S2, N2, K2, O1, K1, the wind is out of interpolated measurements over the whole shelf area. The wind has a resolution of about 42 by 42 km, and a time resolution of 3 hours.

The results for the validation of the GBM are shown in figure 4. Here a gauge (Trischen-West s. Fig. 2) in the area of the Meldorf Bight is used as validation point. The RMS-error for this gauge is about 10 cm which is quite good.

For the sediment transport the velocities have to be of high accuracy rather than the water levels. The water levels for the Meldorf Bight are as good as for the German Bight Model. In order to investigate the velocities of the Meldorf Bight Model a ADCP-measurement of May 1999 is used for comparison with the simulation of May 1999. The boundary conditions are out of the GBM and the wind is out of the measurements described above again. The comparison for one cross-section in the Meldorf Bight is shown in figure 5.

Because this comparison is just during a very small time window, it is planned to compare values like flow rates in a cross-section over the time.

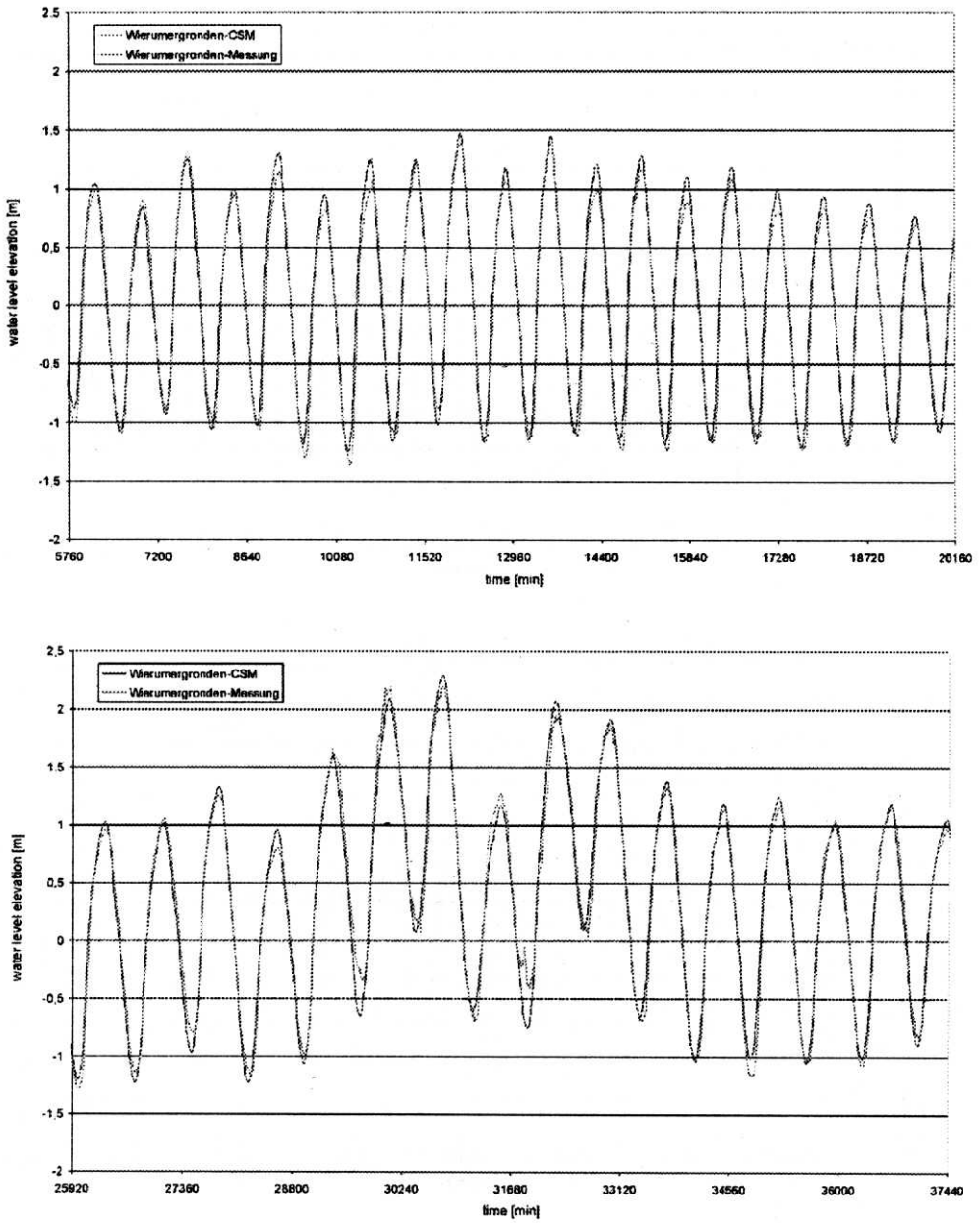


Fig. 3. Comparison of calculated and measured waterlevels in the CSM

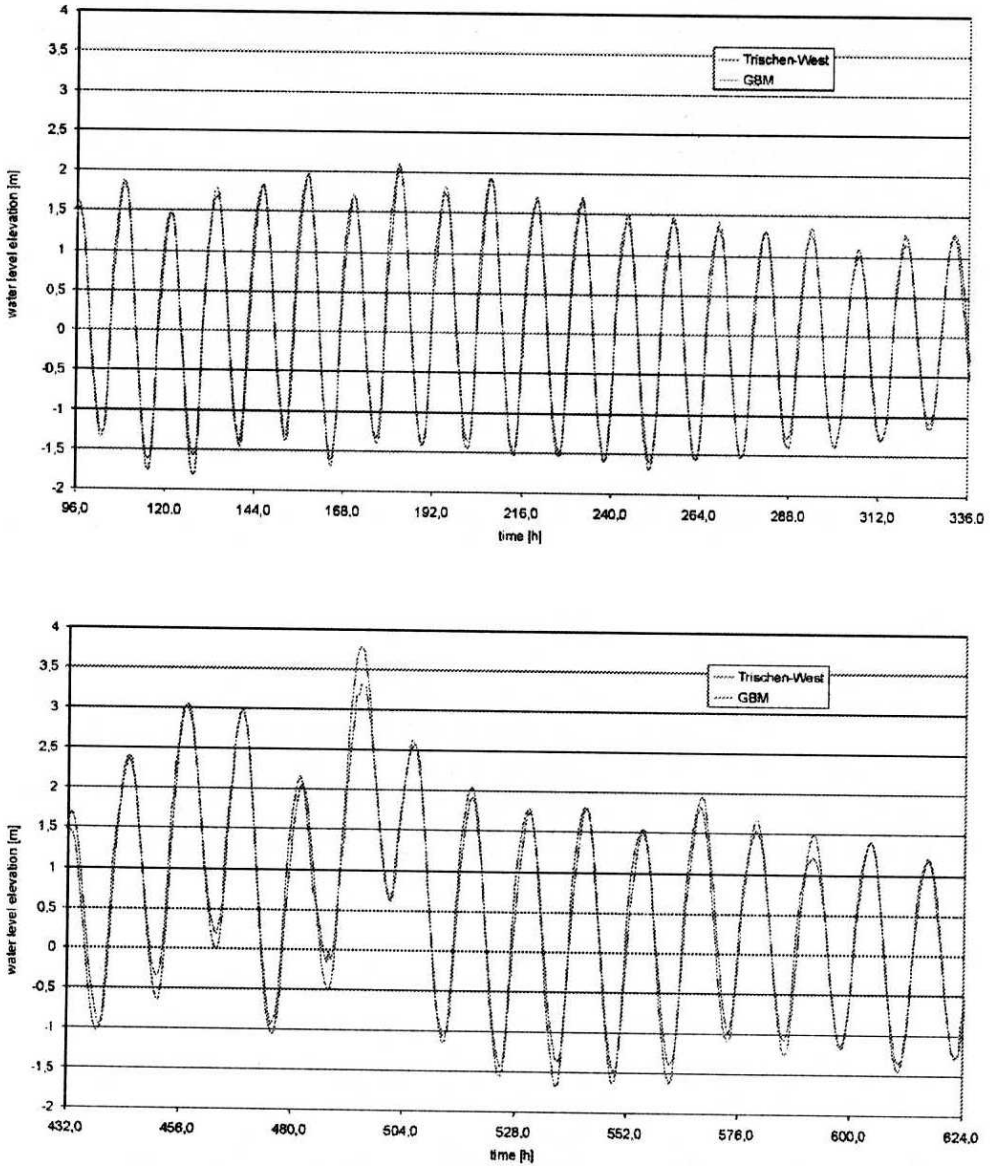


Fig. 4. Comparison of calculated and measured waterlevels in the GBM

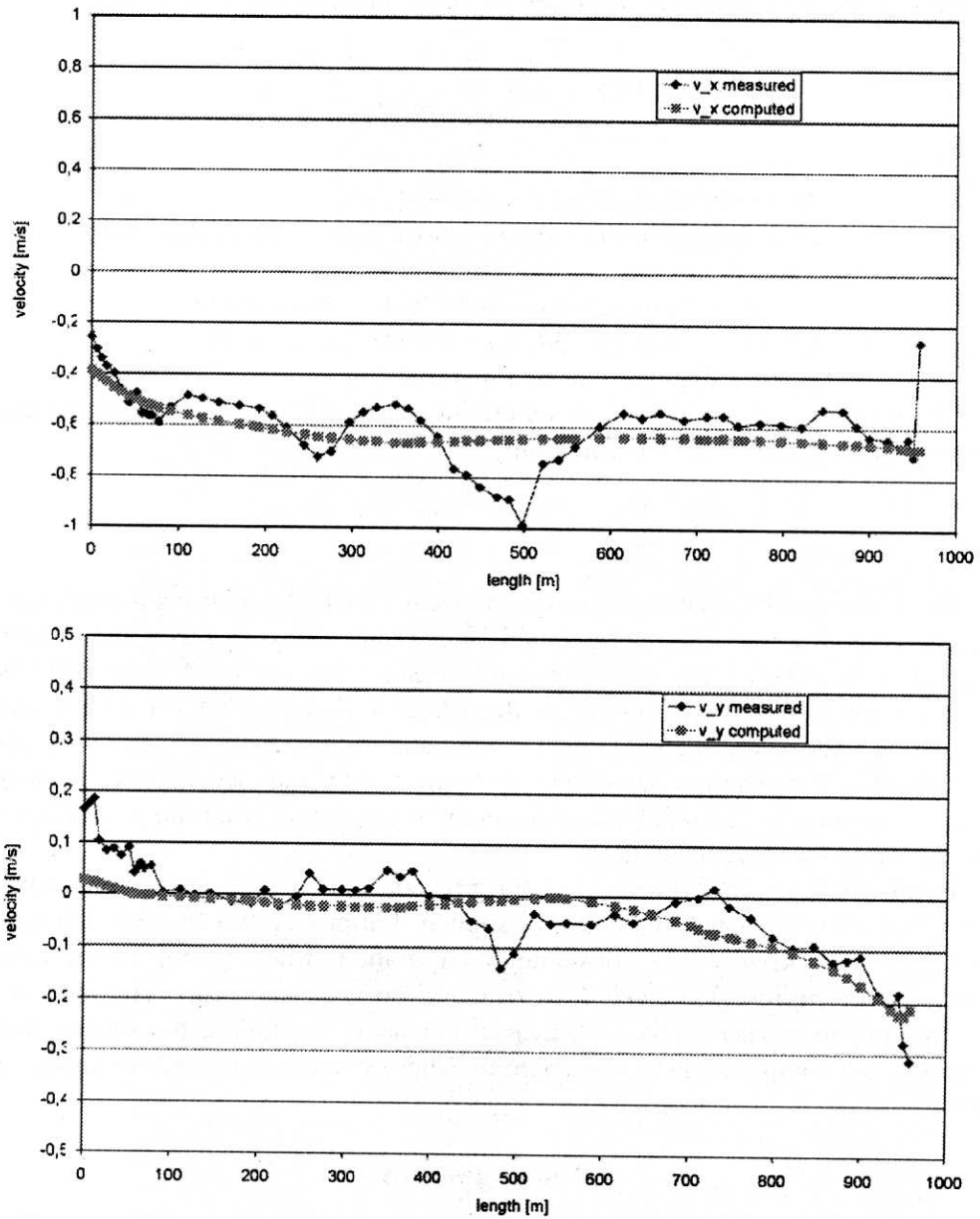


Fig. 5. Comparison of velocities on a transect in the Meldorf Bight

## 6.2. Morphodynamic Modelling

The morphodynamic modelling is done in a first step by bed-load transport. The transport rates are calculated according to the formula of van Rijn (1993):

$$q_{b,c} = 0.005\bar{u}h \left( \frac{\bar{u} - \bar{u}_{cr}}{((s-1)gd_{50})^{0.5}} \right)^{2.4} \left( \frac{d_{50}}{h} \right)^{1.2}$$

in which:

- $\bar{u}$  = depth-averaged flow velocity [m/s]
- $\bar{u}_{cr}$  = critical depth-averaged flow velocity based on shields [m/s]
- $h$  = water depth [m]
- $\bar{u}_{cr}$  =  $0.19(d_{50})^{0.1} \log(12h/3d_{90})$  for  $0.0001 \leq d_{50} \leq 0.0005$
- $\bar{u}_{cr}$  =  $8.50(d_{50})^{0.6} \log(12h/3d_{90})$  for  $0.0005 \leq d_{50} \leq 0.002$
- $d_{50}, d_{90}$  = particle diameters of bed material [m]

The transport rates are used to determine the bed level changes due to the depth-integrated mass-balance equation:

$$\frac{\partial z_b}{\partial t} + \frac{\partial q_{b,x}}{\partial x} + \frac{\partial q_{b,y}}{\partial y} = 0.$$

This equation is solved in the programsystem FREEFLOW using a predictor-corrector scheme with the Heun-formulation. Using this coupled model, a first attempt for simulating the morphodynamical behaviour in the Meldorf Bight is done. Starting on the bathymetry in the Meldorf Bight of 1993 a continuous calculation under natural conditions, i.e. wind and water elevation, over two years is made. The bathymetries are shown in figure 6. One can see that in the area which is zoomed in, the computed behaviour of the depth evolution is similar to the measured bed level changes.

Because of this very time consuming procedure, strategies for sparing computational time will be developed and applied. Latteux (1995) showed different strategies to avoid very time consuming computations when systems under tidal action are of interest. He divided his strategies in two main tasks. The first one has the aim to reduce the cost of hydrodynamics computation, the second one concerns the computation of bed changes. These computations will be made in 2001.

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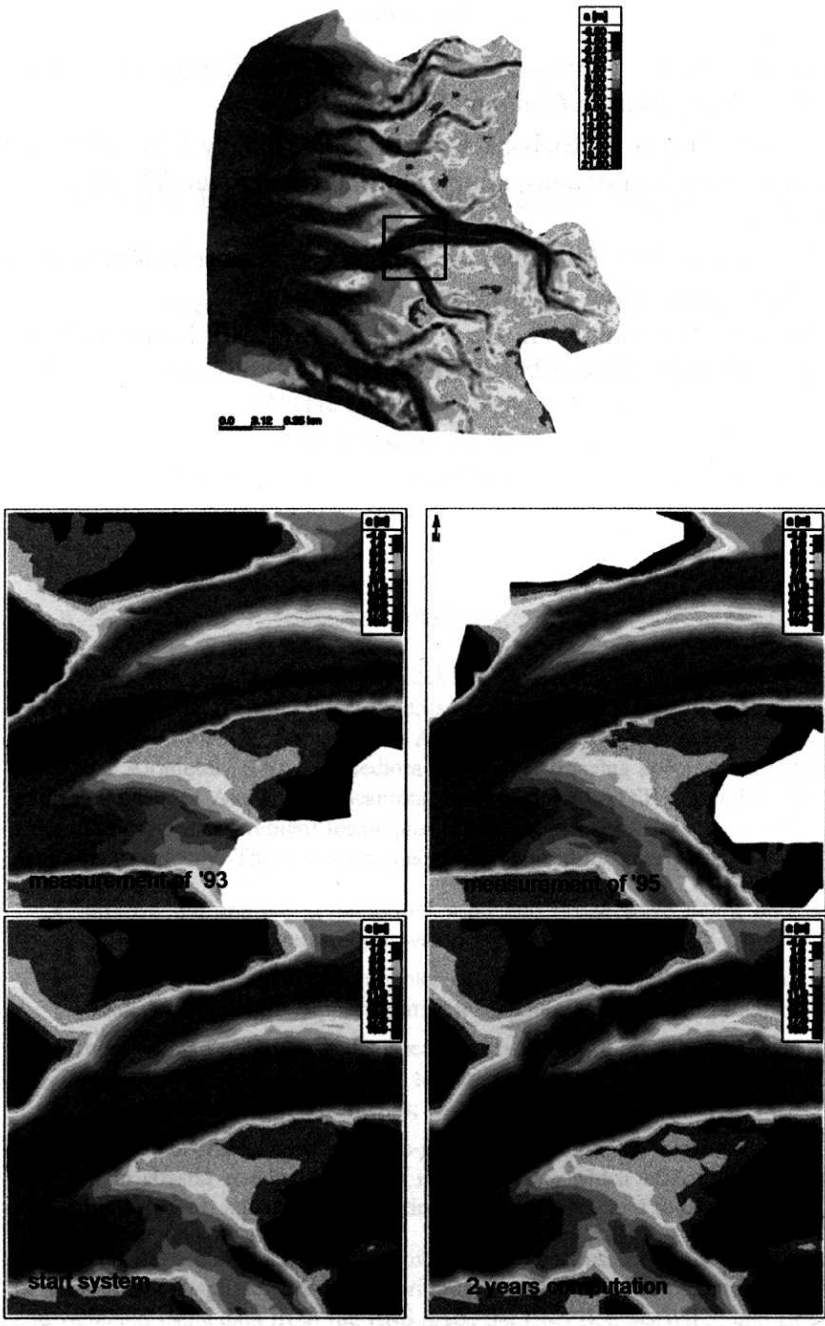


Fig. 6. Comparison of computed and measured changes of depth

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