VISUALIZATION OF ADCP MEASUREMENTS AND 3D NUMERICAL MODEL RESULTS

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ABSTRACT

Hydrodynamics in rivers, estuaries and coastal seas are complex to model, due to phenomena itself and available data (e.g. water levels, velocities, fluxes) for calibration and boundary conditions.

ADCP measurements are an ideal technique to determine velocity profiles also for wide irregular shaped cross sections.

Thus, a flexible tool for accurate comparison of ADCP measurements with numerical model results in time/space domain is needed. The methodology has to be embedded in a generic software approach to make measurements from different devices comparable with results from different models.

Necessary functionality was successfully implemented in the object oriented software application DATATOOL$^{©}$. Applicability is illustrated for MIKE3$^{®}$ model results compared with measurements from ADCP.

Keywords: data mining for knowledge discovery, data and modeling systems, ADCP measurements, comparison of model results and measurement data

INTRODUCTION

Modeling of 3D-hydrodynamics in rivers, estuaries and coastal areas requires data for model calibration and parameter identification (boundary conditions, such as flow velocities) for later prognosis. Availability and accuracy of data determines later quality of model results.

ADCP measurements are ideal to determine flow velocities with high resolution in time/space domain. Comparison of these measurements by-hand is difficult to achieve, time consuming and nearly impossible to document for quality control purposes during calibration of numerical models.

Thus, the software application DATATOOL$^{©}$ was developed under an object oriented framework in JAVA2 using the JAVA3D API for visualization of flow fields and calculated differences between measured and calculated velocities.

Basic technology, functionality and application are shown comparing MIKE3$^{®}$ model results with ADCP measurements.

BASIC TECHNOLOGY
HYDRODYNAMIC MODELING USING MIKE3[®]

The hydrodynamic module (HD-module) in MIKE3[®] is based on a finite difference scheme using a rectangular mesh (Fig. 1).
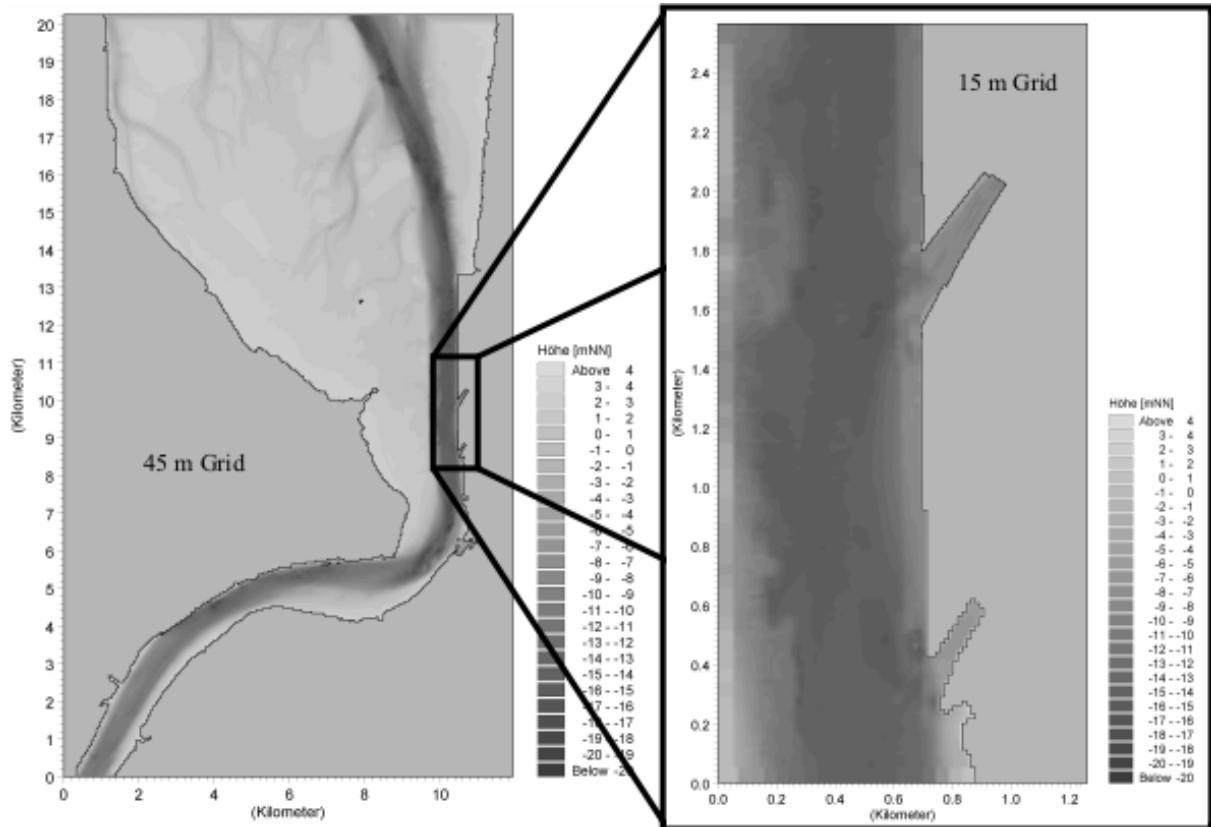

Figure 1: Example of a rotated Finite-Difference Mesh using Nested Grid Option (Mouth of Weser Estuary near Bremerhaven: Δx = 45m, Δy = 45m, Δz = 1m, 15 layers, angle of rotation = 28.5°, nested grid: Δx = 15m, Δy = 15m, Δz = 1m)

Well known theory for simulation of unsteady three-dimensional flows using MIKE3[®] is well known, so skipped here.

Multiple grid option, to nest areas of special interest and/or importance for the phenomena, is available. Rotation of the whole mesh can bring main transport direction through the numerical mesh in accordance with nature, thus ensuring exchange of mass and momentum vertical to cell boundaries.

ACOUSTIC DOPPLER CURRENT PROFILER MEASUREMENTS

Acoustic Doppler Current Profiler (ADCP) devices, contrary to the conventional point measurements by wings and Acoustic Doppler Velocimeter (ADV), can record vertical profiles over the whole water depth (Fig. 2).

Lining up vertical profiles for irregular shaped tracks gives a picture of actual flow velocities over the section. Each vertical profile is going into the records with his unique horizontal position and timestamp.

Horizontal and vertical resolution of measurements is variable. The system determines water depth, velocity of the boat and flow velocity. Therefore, ultrasonic impulses sent by the transducer are reflected by particles and received with a frequency shift used to calculate flow velocities.
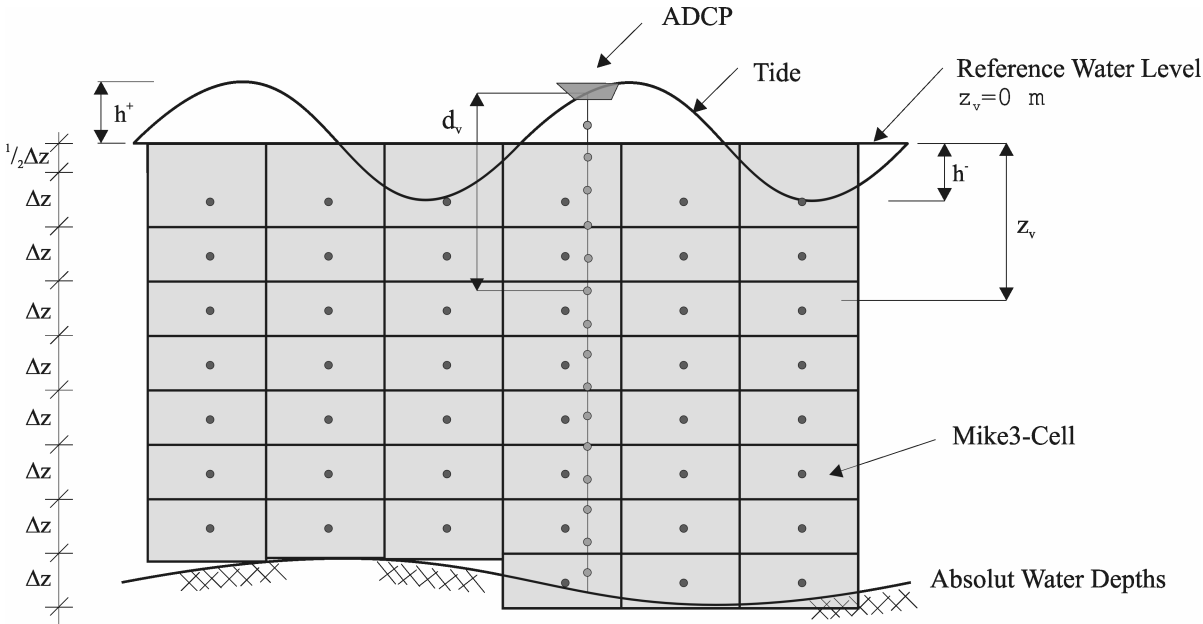

Figure 2: Measured Profiles over the whole Water Depth by ADCP Devices

DATATOOL©

The application is an efficient software system to import, convert, handle, visualize and compare accurately flow velocities in 3D. Providing a tabular and graphical comparison, the program gives an inside view to flow characteristics along tracks and evaluates automatically differences to numerical model results not being made visible by conventional methods.

CONVERSION OF ADCP FILES

Within the ASCI-output file measurements are summarized for each point in a paragraph. General information (position of the boat taking the vertical profile, pitch, roll, heading, timestamp), the distance put back and the echo intensities are given as header information for each vertical velocity profile.

For comparison, positions are converted from WGS-84 to Gauss-Krüger and depth information is brought to reference level (e.g. mNN) by using all available header information. Measured velocities are linked to these positions. Final results of this procedure are accurate positions in x,y,z-coordinate system for every single measurement point and related data linked to this point.

CONVERSION OF MIKE3® FILES

The header of MIKE3® output files gives general information about model area and time resolution. The records follow in tabular form for each time step (tstep), data type (item) and depth level (layer).

For comparison, each individual node/cell is transferred to Gauss-Krüger coordinates and referenced to datum (e.g. mNN).

TABULAR COMPARISON
For tabular comparison, measured velocities in the vertical profile (marked by his position of timestamp) are (a) sorted and linked to the appropriate nodes of the numerical model, (b) interpolated (e.g. inverse distance) to node position and (c) linked to the next identified time step of the numerical simulation (Fig. 3).
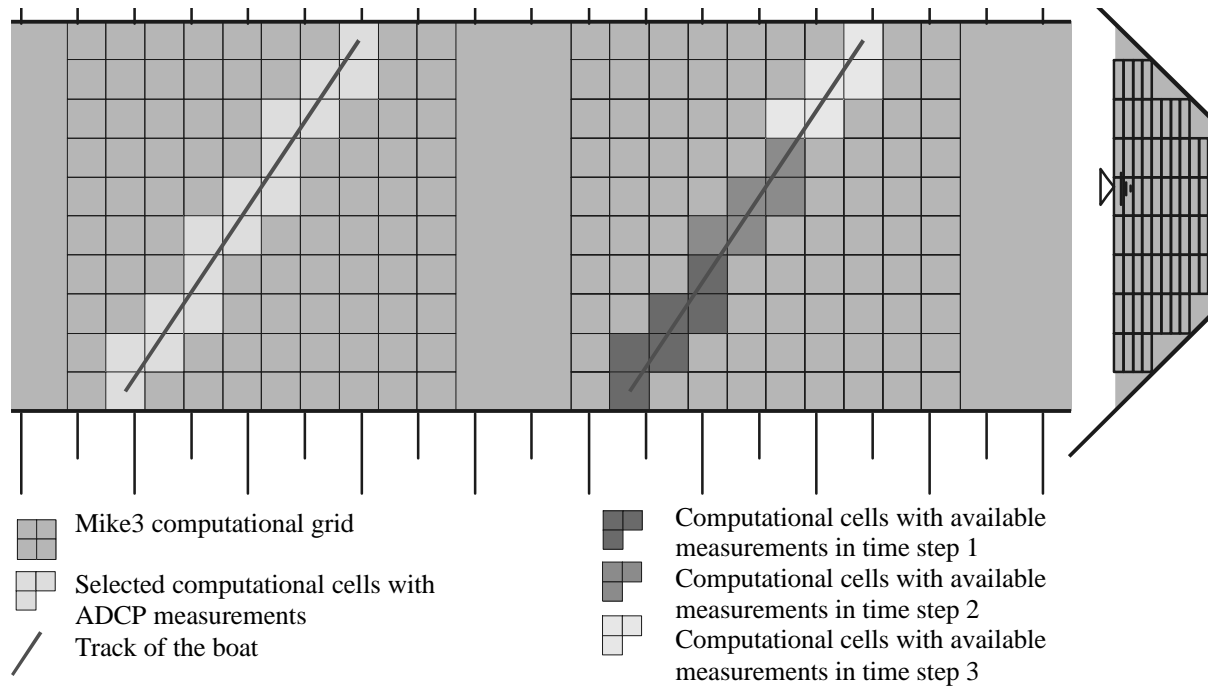

Mike3 computational grid

Selected computational cells with ADCP measurements

Track of the boat

Computational cells with available measurements in time step 1

Computational cells with available measurements in time step 2

Computational cells with available measurements in time step 3

Figure 3: Selection of computational Nodes for Comparison

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ADCP-File: E:\DataTool\adcp_mike3\bhv1041t.m3e
Mike3-File: E:\DataTool\adcp_mike3\kontny_brhv.m3e
dx: 15.0 dy: 15.0 dz: 1.0
```

datum,	zeit,	x (mike3),	y (mike3),	z (mike3),	I,	j,	k,	mVx,	mVy,	mVz,
11.9.2000	16:38:0	3469477.388	5937471.803	-9.000	4	12	7	-0.009	-0.009	-0.009
11.9.2000	16:38:0	3469477.388	5937471.803	-8.000	4	12	8	-0.012	-0.012	-0.012
11.9.2000	16:38:0	3469477.388	5937471.803	-7.000	4	12	9	-0.019	-0.019	-0.019
11.9.2000	16:38:0	3469477.388	5937471.803	-6.000	4	12	10	-0.017	-0.017	-0.017
11.9.2000	16:38:0	3469477.388	5937471.803	-5.000	4	12	11	-0.010	-0.010	-0.010
11.9.2000	16:38:0	3469477.388	5937471.803	-4.000	4	12	12	-0.011	-0.011	-0.011

aVx,	aVy,	aVz,	dVx,	dVy,	dVz,	minX,	minY,	minZ,	maxX,	maxY,	maxZ
-0.355	1.260	0.049	0.346	-1.269	-0.058	-0.704	1.136	-0.173	0.026	1.438	0.160
-0.343	1.307	0.052	0.331	-1.319	-0.064	-0.808	1.130	-0.157	0.098	1.460	0.149
-0.415	1.425	0.059	0.395	-1.444	-0.079	-0.885	1.309	-0.158	-0.029	1.534	0.197
-0.574	1.388	0.091	0.556	-1.405	-0.108	-1.066	1.288	-0.150	-0.093	1.543	0.205
-0.598	1.435	0.078	0.588	-1.445	-0.089	-1.077	1.208	-0.157	-0.143	1.857	0.216
-0.716	1.382	0.076	0.705	-1.393	-0.087	-1.036	1.244	-0.158	-0.349	1.533	0.240

StdabwX,	StdabwY,	StdabwZ,	Anzahl der ADCP-Daten in der Zelle
0.248	0.110	0.120	6
0.297	0.114	0.106	6
0.289	0.098	0.119	6
0.314	0.095	0.127	6
0.306	0.221	0.126	6
0.228	0.123	0.131	6
...			

Table 1: Tabular Comparison of ADCP Measurements and MIKE3[®] Model Results

The tabular comparison of ADCP and MIKE3$^®$ calculations (Tab. 1) gives detailed information about differences in each grid cell of the computational domain measured values are available.

The comparison is mainly used to calibrate numerical models with high resolution in space, where accuracy is required and small differences in model calibration influences quality of later results. It is also used to detect measurement errors. Within the tabular comparison, following information for each computational node with measured velocities is available:

- Time step of the numerical calculation,
- Position (x,y,z) of the computational node,
- Measured flow velocities (interpolated) at this computational node,
- Calculated flow velocities at this computational node,
- Differences between measured and calculated values,
- Minimum and maximum of measured velocity components,
- Standard deviation of measured velocity components and
- Number of available ADCP measurement points for this computational node.

Statistical values (maximum, minimum, standard deviation) for incorporated measurements provide a view to quality of available data. In this way errors during the measurement campaign can be detected and areas with spare knowledge base about the flow field are taken off from comparison. The resulting table can be exported to EXCEL.

VISUALIZATION OF RESULTS BY GRAPHIC ANALYSIS
Due to the huge amount of tabular data coming from an ADCP track of several minutes, a more sophisticated solution for faster detection of differences and errors was needed to satisfy rapidly user requirements during model calibration.

Thus, the package GRAPHIC ANALYSIS, making intensive use of JAVA3D API functionality, was developed. Having tabular comparison in background, it is possible to specify individual x- or y- cross sections for local comparison and visualize results in detail using a separate window. Hydrodynamic situations can be shown in vector and/or scalar form.

The applied method is fully object oriented, making sure that basic behavior of graphical objects can be transferred to other applications, being necessary to compare measurements with model results coming from FV and FE schemes.

The following aspects were considered for development of the tool (Fig. 4):
- Rotation in all directions,
- Free selection of cross sections through the computational domain and
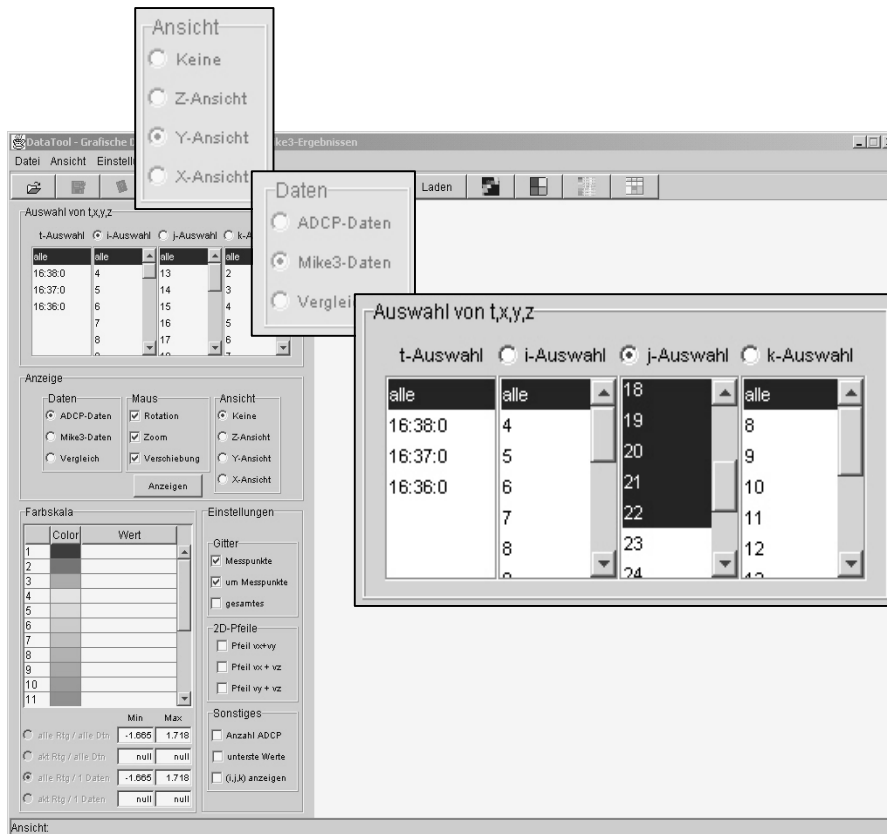- Flexible use of colors and vector plots adjustable to special user needs.

Figure 4: Time Step Selection, Color Shading and Data Selection in DATATOOL[©]

COMPARISON OF ADCP MEASUREMENTS AND NUMERICAL MODEL RESULTS: TEST CASE BREMERHAVEN

Fig. 5 and 6 give a first impression to the application for the test case Bremerhaven (Fig. 1).

Fig. 5 shows an irregular ADCP track in west – east direction with selected computational cells for comparison. Cells are only selected if associated data is available. By rotation and zoom other cells can be viewed easily.

Fig. 6 shows differences, scalable to make errors and necessary model adaption visible.

Quality of underlying data (statistics of measurements in single computational not shown in Fig. 6), is also available as background information. Area of interest can be rotated and zoomed in all directions. Visualization can be restricted to single columns and/or cells to focus on flow phenomena in detail. Time steps can be selected as single events or switched on for a longer time sequence to get a movie of differences (if sufficient track data is available).

Comparison of different tracks (same track for other tidal phases and/or same tidal phase for different tracks) is possible for different track parameters (e.g. mean difference of flow velocities, maximum and minimum difference, standard deviation).

Contents of the graphic area can be exported to common bitmap formats. In a future version an underlying geo referenced bitmap will be available.
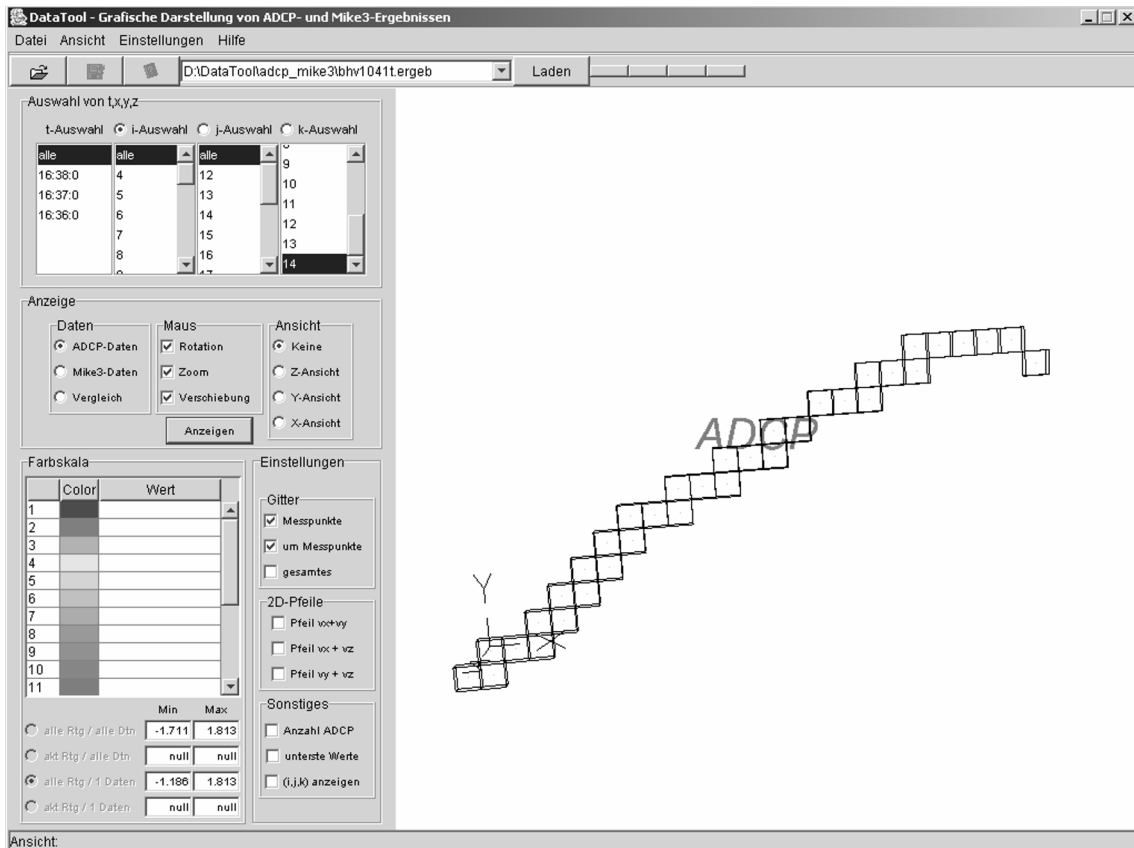
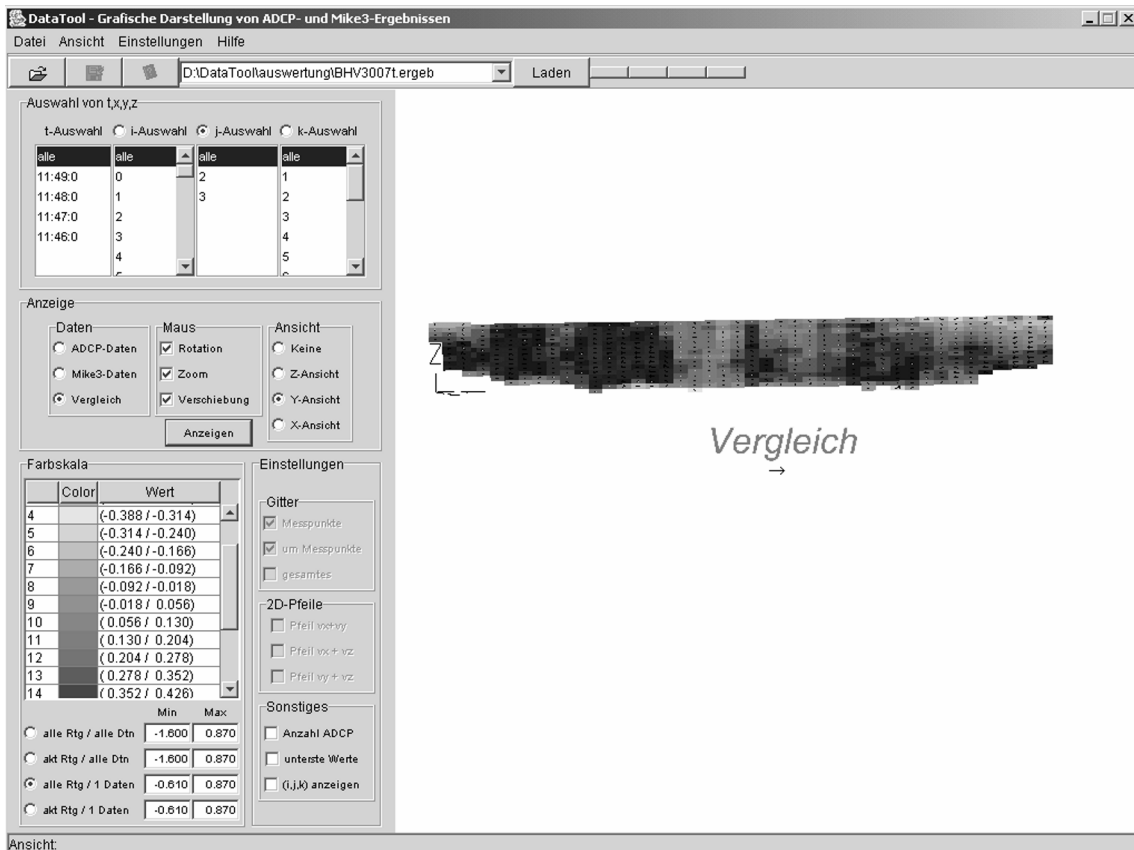Figure 5: Cross Section for a local Comparison (Track of ADCP Measurements)

Figure 6: Comparison of MIKE3 Results and ADCP Measurements

CONCLUSIONS

DATATOOL$^{©}$ is a flexible and accurate solution for comparison of ADCP measurements and results of numerical models.

The object oriented approach is open for adoption to FV and FE schemes.

The applied methodology of comparison gives an inside view to flow characteristics making an accurate selection of computational node where field data is available. Selection of adequate numerical time steps guarantees best comparison, because timestamps of ADCP measured vertical profiles are not transferred to an averaged timestamp for the whole cross section track.

Thus, the applied methodology gives an adequate solution for comparing field measurements and model results with highest resolution in space and time.

ACKNOWLEDGEMENTS