OpenDA applications

Calibration of SWAN for the Wadden Sea using SWAN-CI

SWAN

The SWAN wave model describes the behaviour of wind generated waves in coastal regions and lakes. It accounts for wave generation by wind, wave propagation, shoaling, refraction, diffraction and dissipation processes like white-capping, bottom friction, depth-induced breaking.

All these process descriptions contain model parameters. For all parameters default values are available. These are not per definition the optimal settings for a specific area of interest. By varying model parameters, and comparing model results with available wave measurements, the model parameters can be chosen such that the model approaches the observations best (“model calibration”).

OpenDA and SWAN-CI

OpenDA is a strategic software environment for operational data assimilation, model uncertainty analysis and model calibration. OpenDA is a generic system with identical look and feel when used with process models. It can be linked to any process model using a model wrapper that takes care of the data exchange between OpenDA and that process model. The OpenDA concept keeps developments of process models separate from data assimilation developments, allowing for generic optimisation of its routines. Its setup offers the possibility to re-use modules, it makes functionality extension easier and it steepens the learning curve for the user.

The SWAN Calibration Instrument (SWAN-CI) is a dedicated SWAN model wrapper around OpenDA to further facilitate SWAN model calibration for the user. The user can select several SWAN model applications, each with its wave measurement data, to calibrate uncertain model parameters simultaneously over all selected model applications using any of the available OpenDA calibration / optimisation routines.
The difference between observations and model results is expressed in the following Goodness of Fit criterion, which is minimised during optimisation:

$$GoF = \frac{1}{2}\sum_{i=1}^{N_i} w^i_{H_{m0}} \left[\left(H^i_{m0,obs} - H^i_{m0,sim} \right)^2 / \sigma^{i2}_{H_{m0,obs}} \right] + \frac{1}{2}\sum_{i=1}^{N_i} w^i_{T_{m-1,0}} \left[\left(T^i_{m-1,0,obs} - T^i_{m-1,0,sim} \right)^2 / \sigma^{i2}_{T^i_{m-1,0,obs}} \right]$$

Here, $\sigma_{H^i_{m0}}, \sigma_{T^i_{m-1,0}}$ are measurement uncertainties; w=1. Given these user selections, the automated optimisation process is objective, quantified, reproducible, efficient and effective.

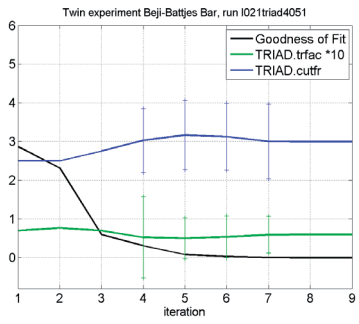

Figure 1: Results twin experiment (Dud with 2 parameters) including uncertainty bound of -2σ +2σ

SWAN model application Wadden Sea

In order to assess a more reliable computation of hydraulic boundary conditions for the Wadden Sea, the optimum SWAN parameter settings must be determined for this tidal flat area with its complex bathymetry. Existing SWAN applications of Amelander Inlet, Friesian Inlet, Eastern Scheldt Mouth, Lake IJssel, Delilah, plus two laboratory applications are considered to comprise the relevant Wadden Sea wave processes.

SWAN Calibration experiment

The aim of the experiment with SWAN-CI is to first perform several single / double parameter sensitivity and optimisation experiments, e.g. for cds3, cfjon, trfac and alfaBP. Based on their results, a simultaneous optimisation experiment was defined for the model parameters cfjon, triad and alfaBP over all 7 applications mentioned above, using a total of 20 application instantiations and 103 measurement data sets of Hm0 and Tm-1,0. As OpenDA optimisation routine DUD without constraints was selected. Based on evaluation of the results of a first set of simulations, DUD proposes adjustment of parameters for an additional simulation, and so on, until convergengence has been reached. The calibration was conducted on a Linux cluster using 8 nodes.

Proof of concept / Results

All sensitivity and calibration experiments were conducted successfully, with the user being able to monitor the convergence of the optimisation process during simulation. Various embedded and easy to evaluate scores were used to assess the results. The final experiment, with 3 parameters and 20 model applications, required several days for convergence on the Linux 8 node system. The final results obtained for the experiments are:

parameters	cds3	cfjon	αBP	trfac
default	0.7	0.067	0.99	0.05
proposed	0.8	0.038	0.96	0.10

Conclusions

The present SWAN-CI application has shown that SWAN-CI / OpenDA can be used in a flexible way to optimise uncertain model parameters and forcing in a single SWAN model application and also over a range of model applications.

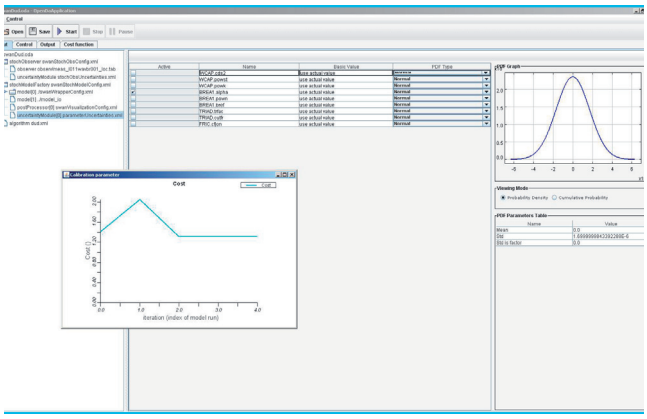

Figure 2: Graphical user interface of the SWAN Calibration Instrument

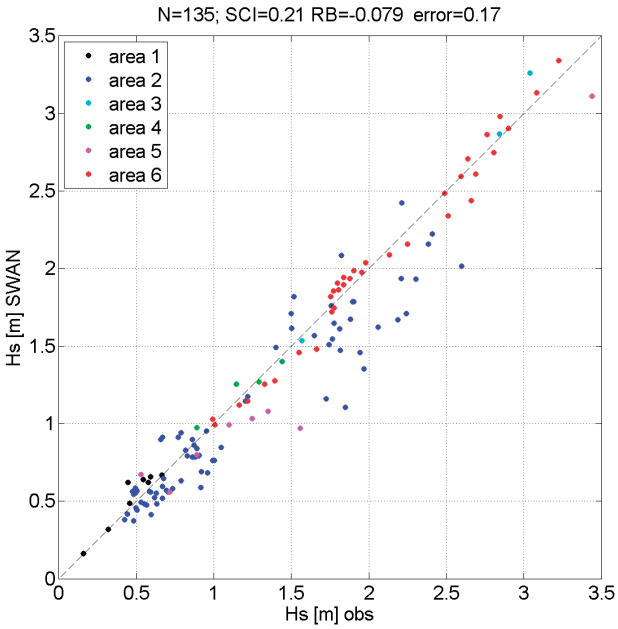

Figure 3: Example of scatter plot of computed versus observed wave height. Colors indicate the various model areas

References

www.openda.org

User Manual Calibration Instrument SWAN, release 2.00.00, Deltares, 2009.