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Enabling Delta Life

The use of the OpenDA SWAN Calibration Instrument

for the Dutch Hydraulic Boundary Conditions

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Introduction

The use of the OpenDA SWAN Calibration Instrument for the Dutch hydraulic boundary conditions

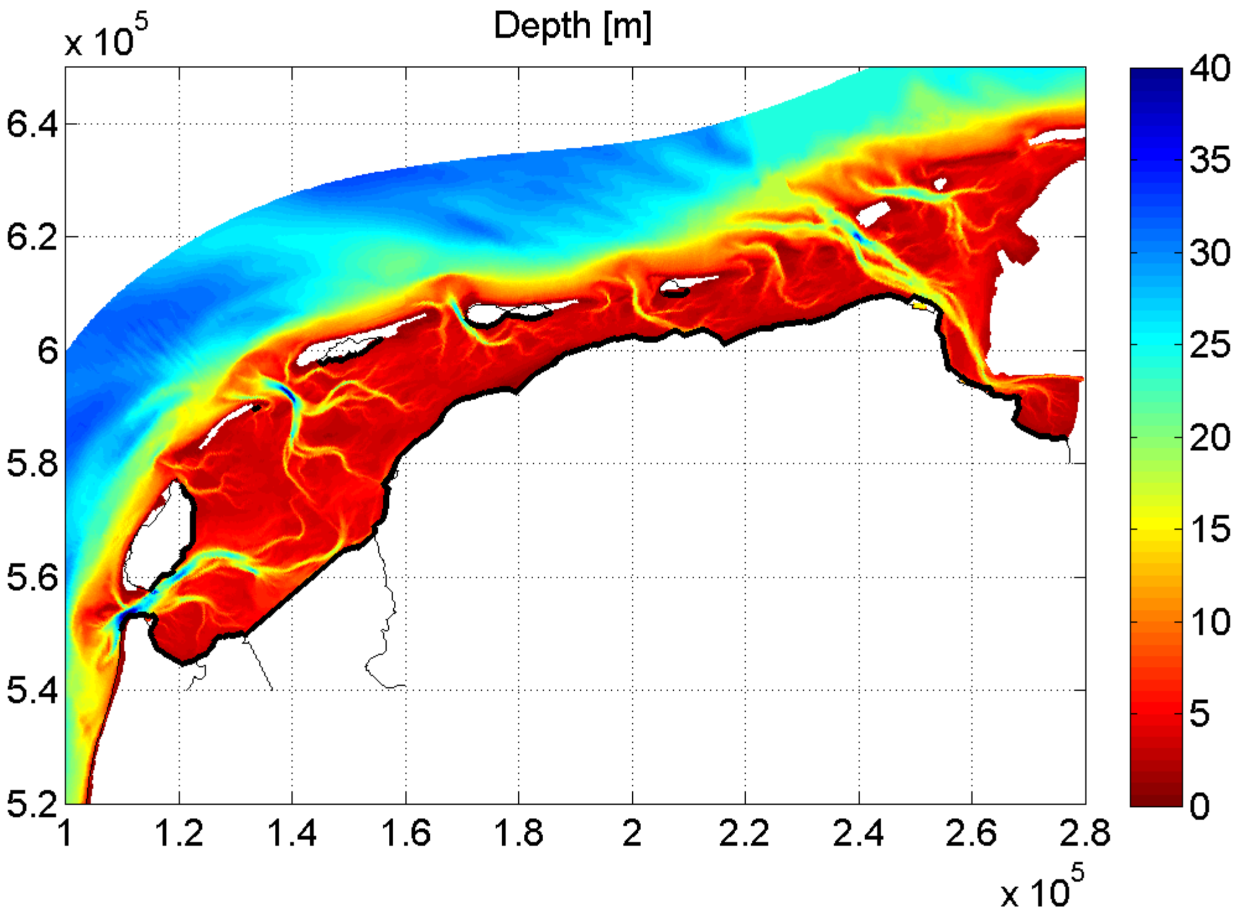
- OpenDA:
  framework for data assimilation and calibration

- SWAN:
  numerical wave model

- SWAN Calibration Instrument:
  software for calibrating SWAN

- hydraulic boundary conditions:
  represent the hydraulic load (water level, wave height, wave period and wave direction) that a flood defence must be able to withstand.

Hydraulic Boundary Conditions



hydraulic boundary conditions

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SWAN

SWAN (Simulating WAves Nearshore) accounts a.o. for:

- wind generation
- wave propagation
- wave dissipation
    - white capping
    - bottom friction
    - depth-induced breaking
- wave interactions
    - quadruplets
    - triads

These process descriptions contain model parameters with default values. Not per se optimal values for a specific area of interest.

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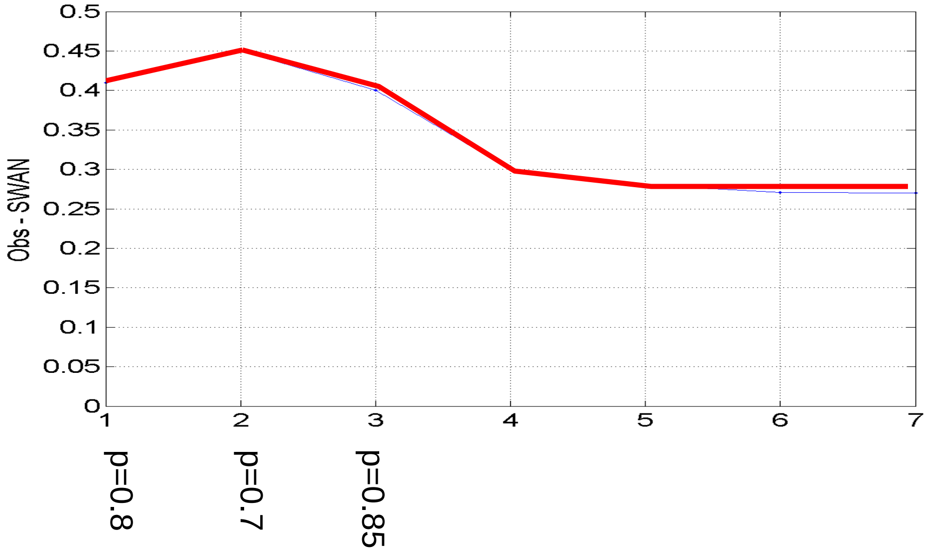
Calibration

Model Calibration

Determine in an efficient, objective and reproducible way the values of SWAN model parameters so that the model approximates wave observations best.



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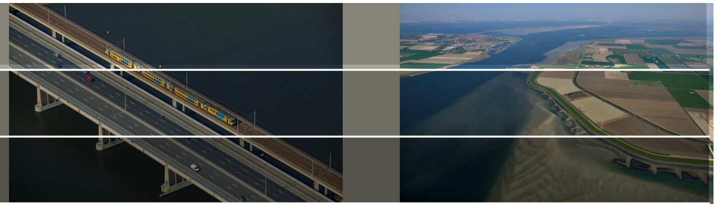
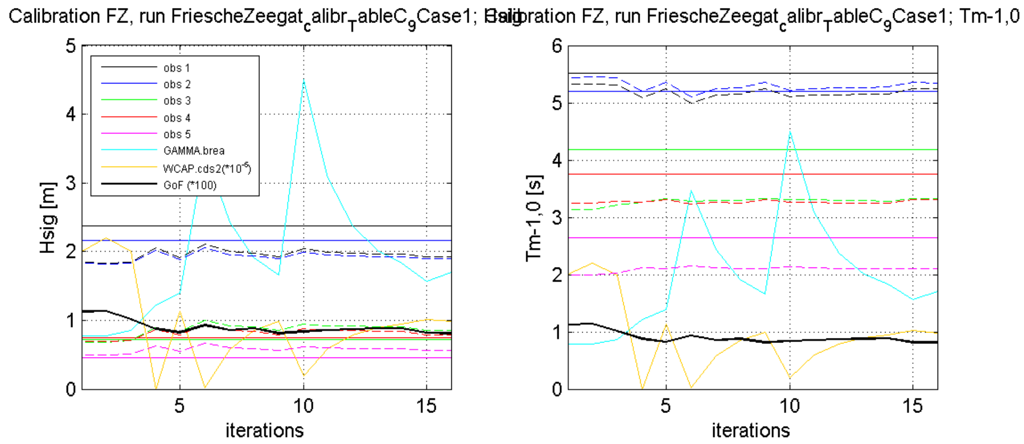
SWAN Calibration Instrument



Model Calibration



- various wave parameters
- various calibration parameters
- simultaneous calibration
- various locations
- nested runs

→ **SWAN Calibration Instrument**

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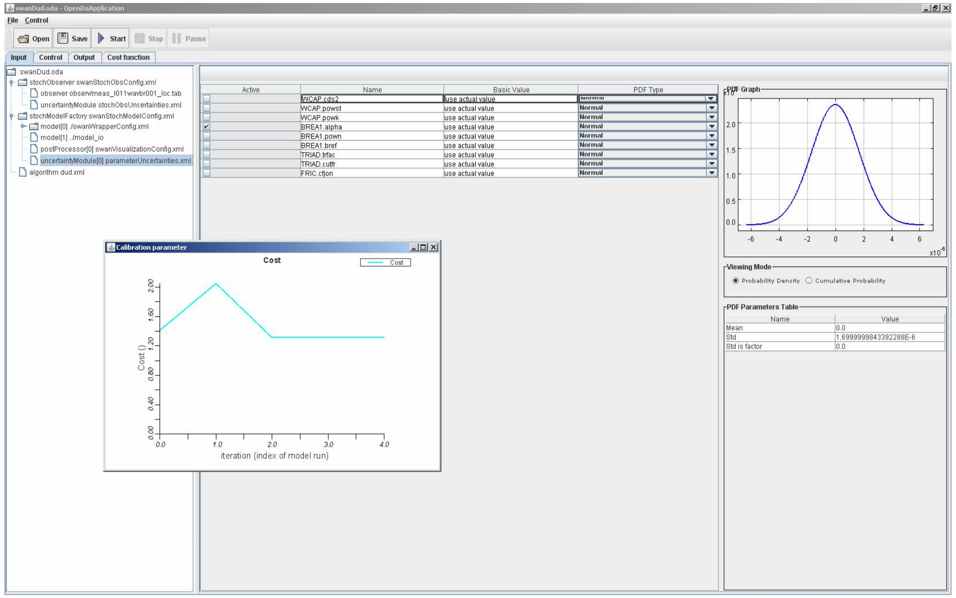
SWAN Calibration Instrument

SWAN Calibration Instrument



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

$$\frac{1}{2}\sum_{i=1}^{N_i} w^i_{T_{m-1,0}} \left[\left(T^i_{m-1,0,obs} - T^i_{m-1,0,sim} \right)^2 / (\sigma^i)^2_{T^i_{m-1,0,obs}} \right] + \ldots$$ *(wave period)*

σ = measurement uncertainties

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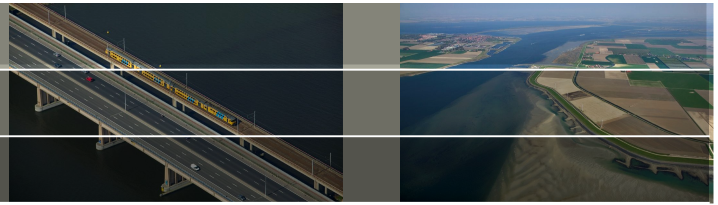
SWAN Calibration Instrument



The variation of individual calibration parameters can be constrained by adding a soft constraint term (*SC*) to the *GoF* (“penalty”)

$$SC = +\frac{1}{2}\sum_{p=1}^{P} w_p \left(\frac{\alpha_p - \alpha_p^{ref}}{\sigma_p^{ref}}\right)^2$$

α_p^{ref}: initial best guess

σ_p^{ref}: measure for the allowed variation

Furthermore, user can define:

- algorithm (Dud, Powell, Simplex)
- accuracy criteria (number of iterations, tolerances etc)
- calibration parameters
- initial parameter values
- uncertainty of calibration parameters
- wave parameters (Hm0, Tp, Tm-1,0)
- measurements (where and when)
- measurement uncertainty / weight

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SWAN Calibration Instrument

The SWAN Calibration Instrument carries out a number of SWAN runs (“evaluations”), varying the values of the calibration parameters.

The new values of the calibration parameters are based on the results of the previous evaluations.

The SWAN Calibration Instrument has no knowledge on wave processes, it just checks whether the GoF increases or decreases.

Application Calibration Instrument for HBC

SWAN calibration for the Hydraulic Boundary Conditions

- Enhanced dissipation in counter currents:	*cds3*	*deep*
- Bottom friction:	*cfjon*	*shallow*
- Wave breaking (biphase model):	α_{BP}	*shallow*
- Triads:	*trfac*	*shallow*

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Application Calibration Instrument for HBC

SWAN cases (=observations + SWAN input) available in SWIVT
http://swivt.deltares.nl

>100 field and laboratory cases

Choose suitable locations within appropriate cases

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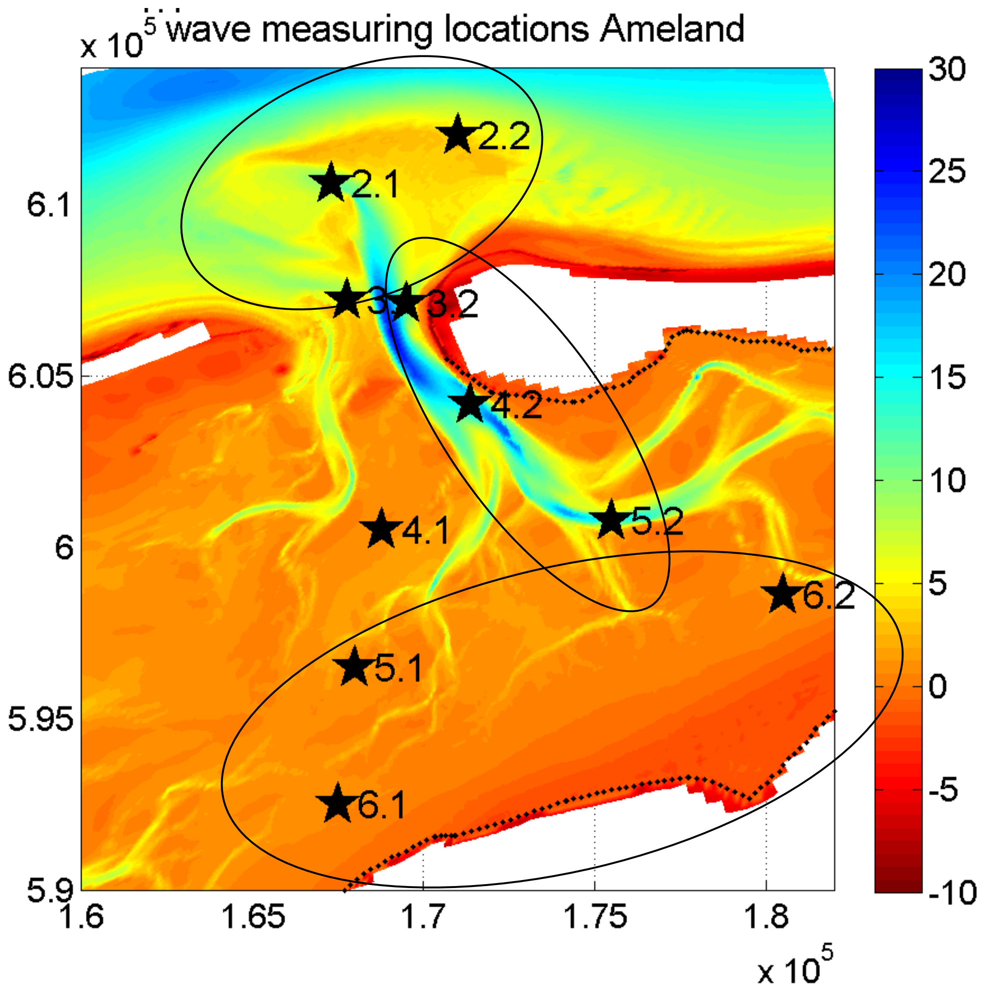
Selection of measuring locations

breaking / triads

dissipation on
counter current

bottom friction



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Calibration of bottom friction

Calibration of bottom friction (*cfjon*)

initial value: 0.067 $m^2 s^{-3}$

uncertainty: lognormal distribution with 80% standard deviation

lognormal distribution prevents negative values

0.03 ~< *cfjon* ~< 0.15

observations: 31 locations (H_{m0} and $T_{m-1,0}$)

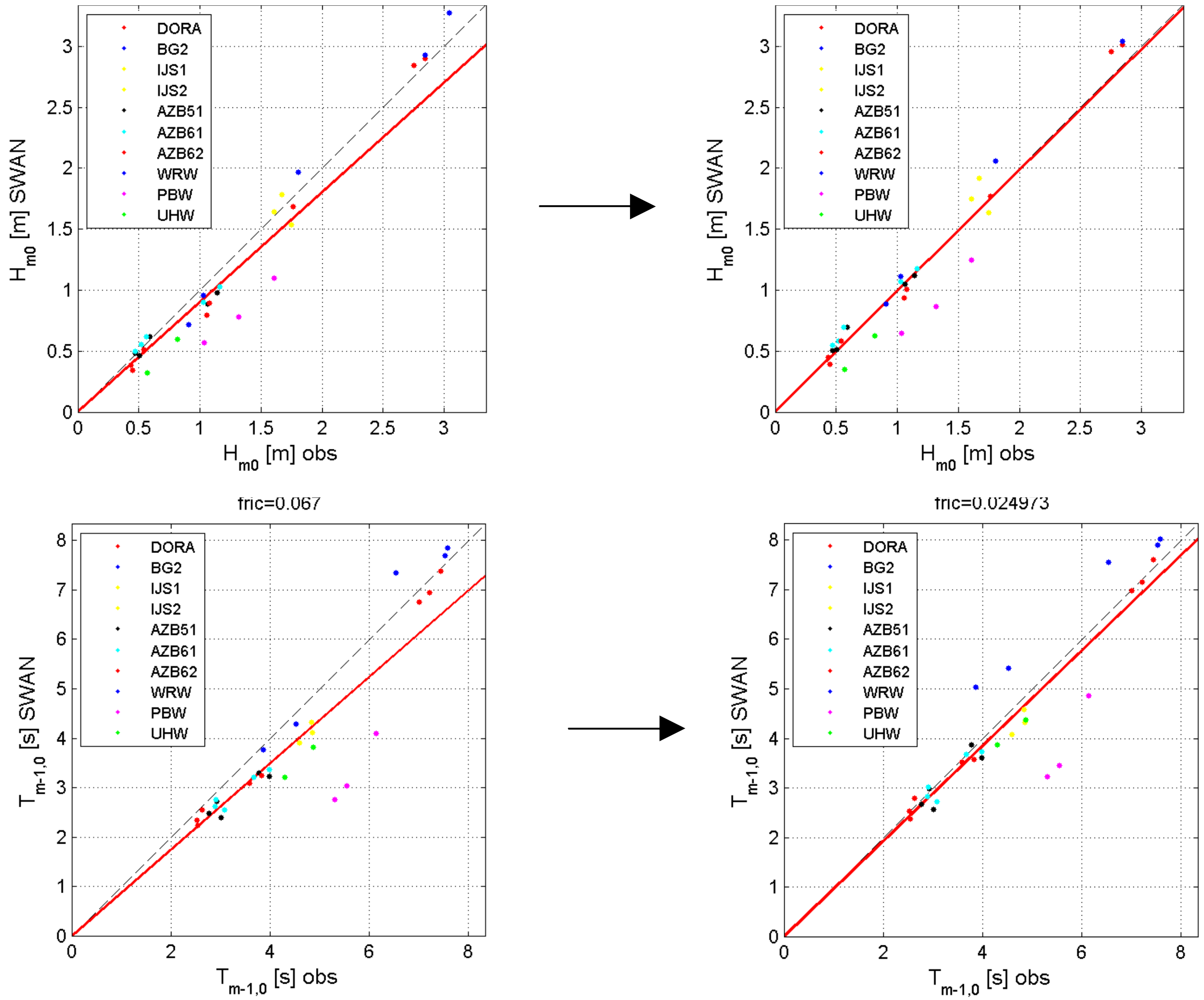
uncertainty: 10%

Result calibrating bottom friction

evaluation 1 (0.067) evaluation 10 (0.025)

H_{m0} [m]

$T_{m-1,0}$ [s]



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Calibration breaking, friction, triads

Calibration of breaking, friction and triads

initial value: α_{BP} =0.99; cfjon=0.025; trfac=0.10

observations: 103 locations within 20 cases in 5 areas

uncertainty σ: different per area, used to give certain weight to the areas. A large uncertainty implies a small weight. 3 samples in Lake IJssel can get the same weight as 29 samples in a laboratory case.

$$GoF = \frac{1}{2}\sum_{i=1}^{N_i} w_{H_{m0}}^{i}\left[\left(H_{m0,obs}^{i} - H_{m0,sim}^{i}\right)^2 / (\sigma^i)^2_{H^i_{m0,obs}}\right] + \ldots$$

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Result calibrating breaking, friction, triads

#	GoF	cds3	alpha	trfac	cfjon	c-Hm0	SI-Hm0	RB-Hm0	c-Tm	SI-Tm	RB-Tm	error
1	447.400	0.800	0.990	0.0800	0.0250	1.0053	0.1249	0.0145	0.8899	0.0941	-0.0167	0.1095
2	506.772	0.800	1.188	0.0800	0.0250	0.9580	0.1473	-0.0308	0.8813	0.0983	-0.0251	0.1228
3	446.690	0.800	0.990	0.1319	0.0250	1.0120	0.1254	0.0215	0.8827	0.0911	-0.0242	0.1082
4	456.535	0.800	0.990	0.0800	0.0556	0.9506	0.1247	-0.0404	0.8343	0.1051	-0.0701	0.1149
5	**421.076**	**0.800**	**0.958**	**0.0996**	**0.0376**	**0.9926**	**0.1195**	**0.0013**	**0.8640**	**0.0906**	**-0.0417**	**0.1051**
6	423.829	0.800	0.990	0.1101	0.0363	0.9880	0.1210	-0.0026	0.8633	0.0903	-0.0427	0.1057
7	421.972	0.800	0.974	0.1047	0.0370	0.9904	0.1202	-0.0005	0.8636	0.0904	-0.0422	0.1053
8	421.875	0.800	0.966	0.1021	0.0373	0.9916	0.1199	0.0005	0.8637	0.0906	-0.0421	0.1052
9	422.029	0.800	0.962	0.1009	0.0374	0.9921	0.1197	0.0009	0.8639	0.0907	-0.0419	0.1052
10	421.126	0.800	0.960	0.1002	0.0375	0.9924	0.1196	0.0011	0.8640	0.0906	-0.0418	0.1051
11	421.172	0.800	0.957	0.0993	0.0376	0.9928	0.1196	0.0015	0.8641	0.0907	-0.0417	0.1051
12	421.199	0.800	0.959	0.0998	0.0376	0.9926	0.1196	0.0013	0.8640	0.0906	-0.0418	0.1051

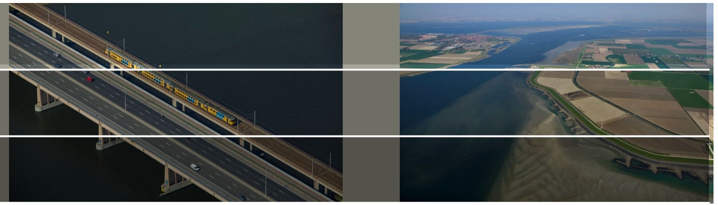
Computational effort for 12 evaluations, 3 parameters, 20 cases:

97 hours (4 days) on eight nodes

Result calibrating breaking, friction, triads

Proposed settings of the calibrated SWAN model

parameters	cds3	cfjon	α_{BP}	trfac
default	0.7	0.067	0.99	0.05
proposed	0.8	0.038	0.96	0.10

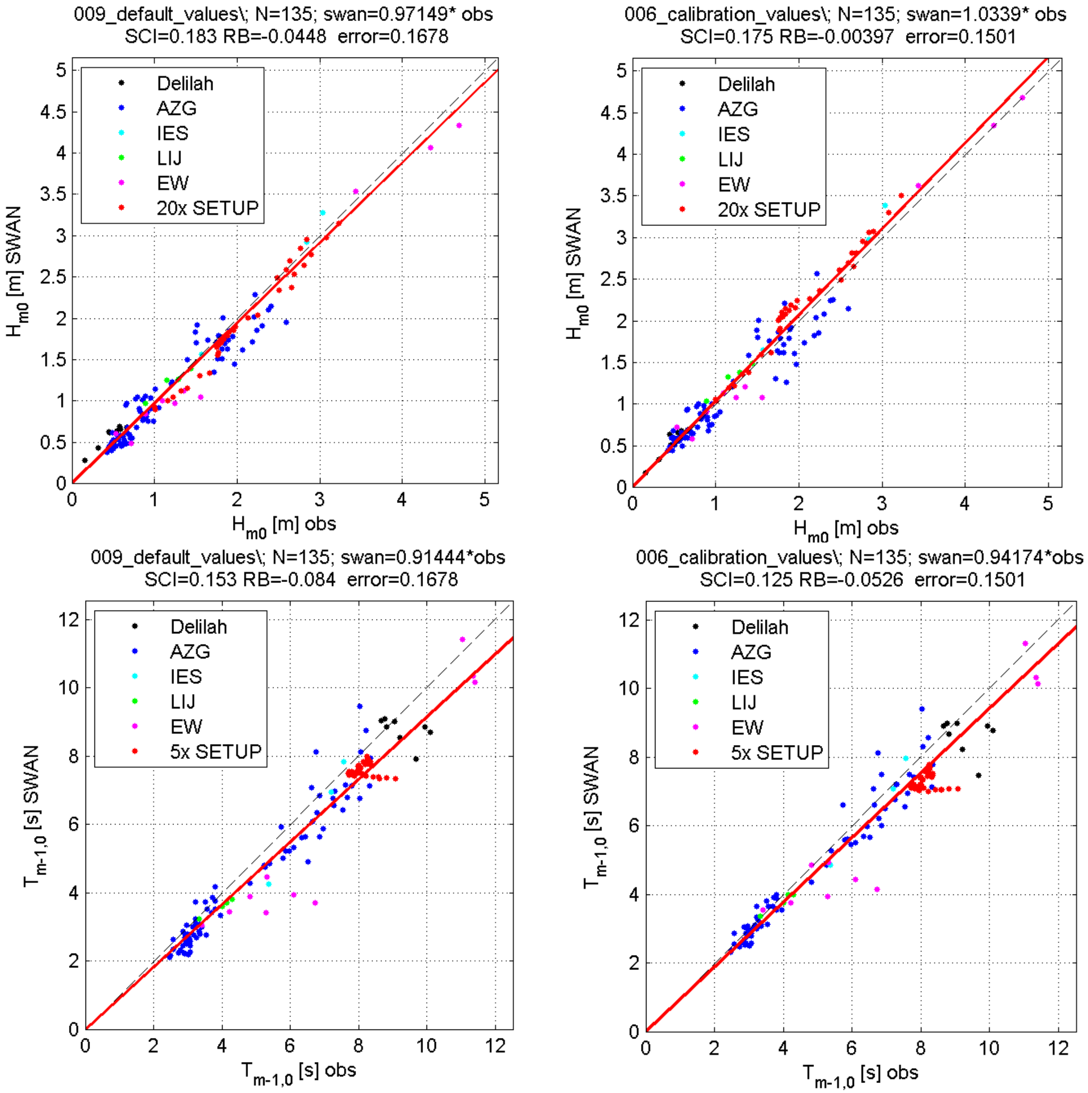


Validation

validation

20 cases

135 samples



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Validation

	Hm0 c	Hm0 SI	Hm0 RB	Tm-1,0 c	Tm-1,0 SI	Tm-1,0 RB	error function
default	**0.98**	0.193	-0.050	0.93	0.141	-0.061	0.167
proposed	1.03	**0.175**	**0.004**	**0.94**	**0.125**	**-0.053**	**0.150**

Scatter Index $$SCI_{\psi} = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\psi_{obs}^{i} - \psi_{SWAN}^{i}\right)^{2}}}{\frac{1}{N}\sum_{i=1}^{N}\psi_{obs}^{i}}$$

Relative Bias $$RB_{\psi} = \frac{\sum_{i=1}^{N}\left(\psi_{SWAN}^{i} - \psi_{obs}^{i}\right)}{\sum_{i=1}^{N}\psi_{obs}^{i}}$$

Error Function $$\varepsilon = \frac{1}{2}\left(SCI_{H} + SCI_{T}\right)$$

Y=c.X

Conclusions calibration

Conclusions on the calibration

In the final calibration, the SWAN Calibration Instrument was used to find simultaneously for 3 model parameters the optimal settings, based on 103 measured samples of bothe wave height and wave period.

Especially the wave period $T_{m-1,0}$ improves with the proposed settings. For the wave height, the differences are small.

Considering the scatter plots, the SWAN results with proposed settings approach the wave observations quite well, especially at the shallow locations of the Amelander Zeegat.

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Reflections SWAN Calibration Instrument

- The SWAN Calibration Instrument uses automated optimisation techniques.
- The present SWAN Calibration Instrument is essentially an analysis tool.
- Use of automated optimisation requires sound knowledge of SWAN and wave processes to guarantee appropriate user choices
- Key user choices: A optimisation technique; B: uncertainties; C: no/yes constraints; D: information content of field data
- Beware: “Garbage in – Garbage out”
- The SWAN Calibration Instrument can be run under Linux and Windows, either with or without a GUI.
- The user has to build up user experience with the techniques (viz. their internal convergence settings)
- Given the above user choices, the process is objective, quantitative, reproducible and tranferable. If used properly, it really is a robust and efficient Calibration Instrument