SWAN and its recent developments

SWAN

Simulating WAves Nearshore

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Abstract

The SWAN model is a third-generation spectral wave prediction model developed by Delft University of Technology. Since its initial release in 1998 this model has become a widely used and reliable tool for offshore and near shore wave predictions. Its main field of application is the coastal zone where, by virtue of its implicit numerical scheme, it can be considered as a very efficient tool for high resolution coastal applications. Besides this field of application it is also appropriate for open ocean conditions.

The source code of SWAN is published, well documented and web served (www.swan.tudelft.nl). Delft University continuously develops and improves SWAN with the support of U.S. Office of Naval Research and Dutch Ministry of Public Works. New features and improved physics are regularly added. This poster provides an overview.

Physics and model features

Wind drag and bottom friction

An alternative to the well-known Wu (1982) wind drag parameterization is added. It is based on a review of a large number of more recent observations, and will gives lower drag values for relatively high wind speeds; see Figure 1. This parameterization has been published in Zijlema *et al*. (2012). In addition, we recommend the use of the lower value of the bottom friction coefficient based on the JONSWAP formulation for both wind seas and swell waves, C_f=0.038 m^{2}s^{-3}, provided the new wind drag parameterization is applied. Using this lower value has also improved the estimates of wave growth in shallow water and of low-frequency wave decay in a tidal inlet, independent of the wind drag.

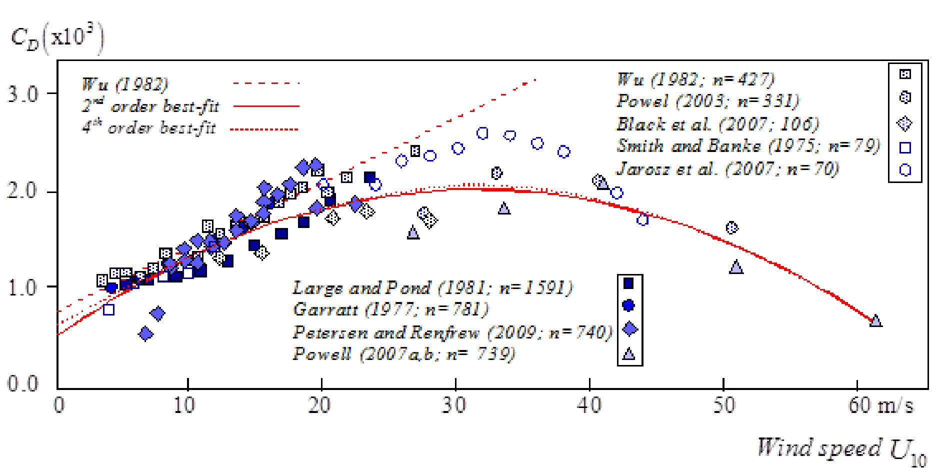

Figure 1. Observed values of the wind drag coefficient from various studies and the weighted best-fit 2nd– and 4th–order polynomial (*n* is the number of independent data points per study).

White capping

It has been known for a long time that SWAN underestimates structurally the peak and mean wave periods. Investigations of Rogers *et al*. (2003) showed that adjusting a specific parameter in the white capping term of WAM Cycle III (i.e. exponent of the mean wave number) leads to an improved prediction of the wave energy at lower frequencies which, in turn, improved the wave periods. This adjustment has led to a new default value in SWAN.

Depth-induced wave breaking

To improve model performance of wave breaking in the depth-limited regions, including bottom slopes, reefs and horizontal flats, a literature study was carried out. This is summarized in Figure 2.

Scatter index	#	BJ'78				TG'83					Bald'98		DDD'85
		0.73	Mad'76	Ting'01+	T&M'02	S&Hol'85	S&How'89	Lipp'96+	vdW'09	FA'12	Rue'03	J&B'07	R&S'03/07
Slopes													
Wallingford*	49	0.06	0.10	0.11	0.18	0.08	0.13	0.16	0.07	0.06	0.07	0.08	0.06
Katsardi*	18	0.13	0.14	0.23	0.34	0.16	0.22	0.24	0.15	0.10	0.16	0.17	0.12
Smith*	31	0.08	0.08	0.13	0.26	0.14	0.22	0.28	0.08	0.11	0.10	0.10	0.09
Boers*	3	0.05	0.07	0.15	0.41	0.19	0.31	0.36	0.06	0.13	0.11	0.08	0.10
B-J*	2	0.05	0.13	0.15	0.34	0.13	0.24	0.32	0.06	0.07	0.07	0.07	0.10
Petten**	8	0.15	0.17	0.19	0.57	0.45	0.53	0.55	0.15	0.23	0.15	0.13	0.15
Horizontal													
Wallingford*	49	0.07	0.07	0.10	0.29	0.11	0.13	0.13	0.08	0.07	0.07	0.07	0.06
Katsardi*	5	0.10	0.10	0.11	0.40	0.19	0.26	0.27	0.10	0.03	0.11	0.11	0.10
Jensen*	45	0.21	0.21	0.37	0.30	0.11	0.14	0.14	0.27	0.21	0.24	0.26	0.26
AZG**	3	0.16	0.15	0.10	0.58	0.47	0.53	0.55	0.10	0.24	0.15	0.14	0.20
Lakes**	5	0.16	0.17	0.08	0.64	0.66	0.71	0.71	0.10	0.27	0.02	0.02	0.11
Guam**	4	0.38	0.29	0.52	0.79	0.41	0.45	0.48	0.56	0.47	0.39	0.29	0.44
Haringvliet**	3	0.16	0.16	0.35	0.51	0.32	0.56	0.60	0.19	0.11	0.20	0.21	0.13
Averages													
slopes	111	0.09	0.12	0.16	0.35	0.19	0.27	0.32	0.10	0.12	0.11	0.10	0.10
horizontal	114	0.18	0.16	0.23	0.50	0.32	0.40	0.41	0.20	0.20	0.17	0.16	0.18
laboratory*	202	0.09	0.11	0.17	0.32	0.14	0.20	0.24	0.11	0.10	0.12	0.12	0.11
field**	23	0.20	0.19	0.25	0.62	0.46	0.55	0.58	0.22	0.27	0.18	0.16	0.20
overall	225	0.13	0.14	0.20	0.43	0.26	0.33	0.37	0.15	0.16	0.14	0.13	0.14

s.i.< 0.10 | 0.10<s.i.<0.20 | 0.20<s.i.<0.40 | s.i.>0.40 | # 1-7 | # 8-12

BJ'78 = Battjes & Janssen [1978]
TG'83 = Thornton & Guza [1983]
Bald'98 = Baldock et al. [1998]
DDD'85 = Dally et al. [1985]
J&B'07 = Janssen & Battjes [2007]
0.73 = fixed in third-generation models
Mad'76 = Madsen [1976]
Ting'01+ = Ting [2001, present authors]
T&M'02 = Tajima & Madsen [2002]
S&Hol'85 = Sallenger & Holman [1985]
S&How'89 = Sallenger & Howd [1989]
Lipp'96+ = Lippmann et al. [1996, present authors]
FA'12 = Filipot & Ardhuin [2012]
vdW'09 = van der Westhuysen [2009]
Rue'03 = Ruessink et al. [2003]
R&S'03/'07 = Rattanapitikon et al. [2003] + Rattanapitikon [2007]

Figure 2. Scatter index of the 12 models based on 13 data sets containing 225 cases of laboratory observations (*) and field observations (**). The highlight colors indicate the two ranges of performance (green and blank) and four ranges of scatter index (from blank to orange).

The main conclusion is that there is no prevailing dissipation model with default settings for the best performance of SWAN under arbitrary bathymetries. Next, a scaling for the well-known Battjes-Janssen model has been developed based on a joint dependency on local bottom slope β and local water depth normalized by wave length *kd* (Figure 3). In addition, this scaling is extended with the effect of directional spreading. This extended β-*kd* scaling is shown to resolve the observed problem of overestimating wave heights over a horizontal bottom and underestimating waves generated by a local wind in idealized 1D shallow lakes. The inclusion of directional spreading has been shown to improve the model for predicting short-crested waves propagating over the horizontal tidal flats.

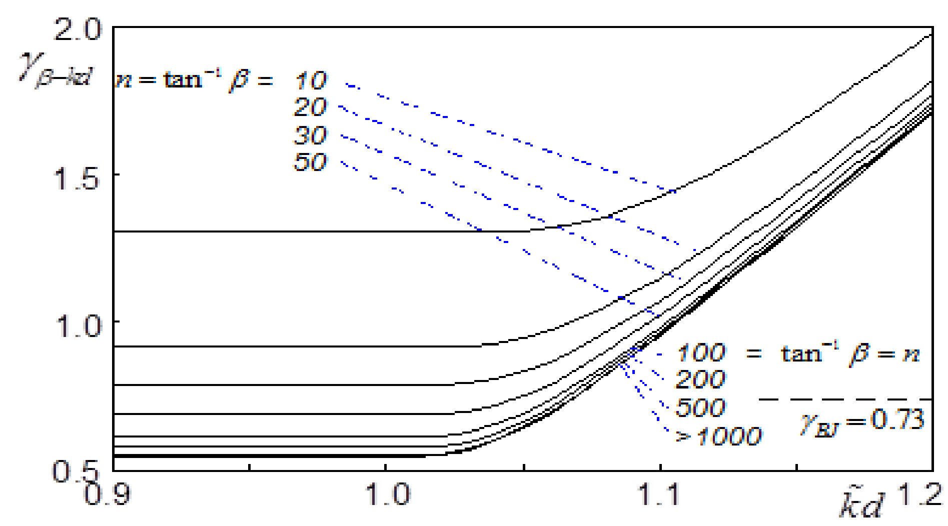

Figure 3. The calibrated γ used in the β-*kd* scaling and γ = 0.73 for reference.

Triad wave-wave interactions

A number of formulations from the literature (Becq-Girard *et al*., 1999, Booij *et al*., 2009, and Toledo and Agnon, 2012) have been implemented to assess their feasibility for operational use in SWAN and to model higher harmonics and the equilibrium spectral tail more accurately compared to the default Lumped Triad Approximation (LTA) of Eldeberky (1999). Some preliminary results are given in Figure 4. We see improvements over the LTA.

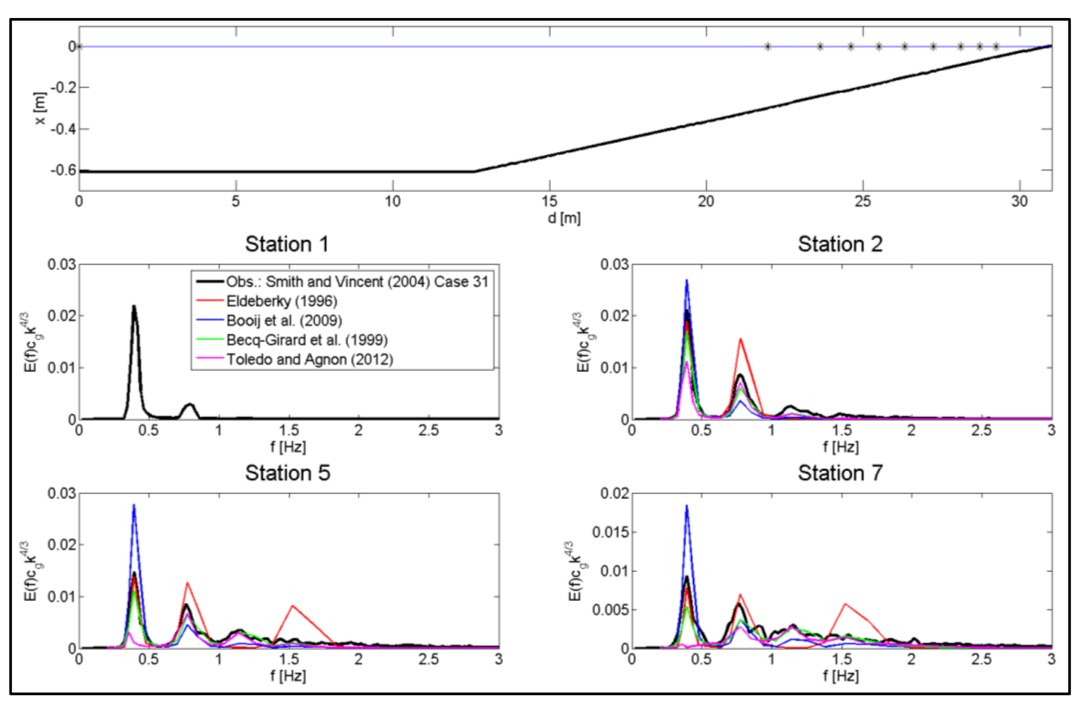

Figure 4. The evolution of the spectrum (stations 1, 2, 5 and 7 in the upper panel), computed with the LTA (Eldeberky, 1996), DCTA (Booij *et al*., 2009) and SPB (Becq-Girard *et al*., 1999) and Toledo and Agnon (2012) triad source terms over a 1:30 flat bed, compared with the spectra observed by Smith (2004). Note that the vertical scale is such that a $k^{-4/3}$–tail, as observed in the surf zone, would appear as a horizontal line.

Unstructured grids

For many coastal applications the use of unstructured grids provides a huge modeling flexibility to have high resolution where needed. Mesh spacings are varied within the application domain using a single, unstructured mesh. This approach is economical, but it can cause accuracy errors in regions where the bathymetry is under-resolved. In particular, excessive directional turning can occur on coarsely-resolved mesh. CFL-limiters have been proposed for the spectral propagation velocities in SWAN (Dietrich *et al*., 2012b). These limiters are not required for model stability, but they improve accuracy by reducing local errors that would otherwise spread throughout the domain.

SWAN-ADCIRC coupling

At present, coupling spectral wave models with circulation models is feasible and is of vital importance for (wave) climate studies and real-time forecasting of waves and storm surge. The tightly-coupled SWAN-ADCIRC model has become a mature tool for realistic high-resolution wave-current predictions in basin scale and inlet scale systems. The combined codes use identical grids and are highly scalable on petascale computers (Dietrich *et al*., 2012a). At Delft University we shall apply this model to the North Sea and Dutch Wadden Sea under extreme storm conditions for the near future. An example is depicted in Figure 5.

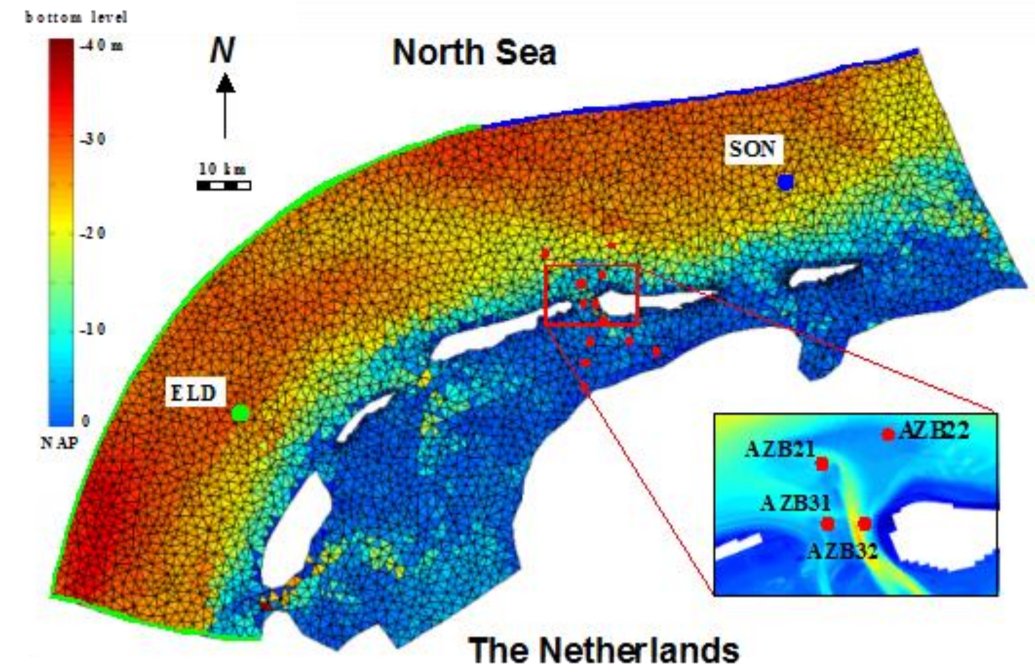

Figure 5. Bathymetry and flexible mesh of the Dutch Wadden Sea.

SWAN and SWASH

SWASH is a time domain, non-hydrostatic wave-flow model that simulates the wave phenomena of interest in coastal regions, including wave breaking, runup, wave-induced currents, wave-current interactions and generation of bound long waves in a realistic wave climate (Zijlema *et al*., 2011). This model has been coupled to SWAN in order to seamlessly propagate wind waves from oceans to coastal waters including sandy beaches, reefs and harbors. A PhD project has been started recently to implement an efficient numerical method in SWASH for nesting moored floating bodies (e.g. ships) for the purpose of studying detailed wave interaction with those objects in harbors and waterways based on a realistic wave climate (Rijnsdorp and Zijlema, 2013).

Other functionalities

An extra source term for wave dissipation by aquatic vegetation has been added based on the work of Suzuki *et al*. (2012).

Recently, a functionality has been implemented in SWAN that enables to generate block and spectral output files in the netCDF format. This may be useful for any kind of operational use, e.g. real-time wave forecasting.

Future developments

In the framework of the NOPP project (Tolman *et al*., 2013) new parameterizations were developed for the source terms. Deep water source terms have been implemented in the WaveWatch III™ model, whereas shallow water source terms have been utilized in SWAN. Progress will be made to implement the new source terms of WaveWatch III™ in SWAN to enhance consistency between these models. Additional developments are related to the efficient and accurate computation of quadruplets using the GMD (Tolman, 2013) and the drag coefficient for very short fetches and under extreme wind speeds (U_{10} > 30 m/s). In the near future, the SWAN model will be extended with a spectral partitioning scheme to enable wave field tracking in large ocean basins to help synoptic wave forecasters.

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