Implementation of New Experimental Input/Dissipation Terms for Modelling Spectral Evolution of Wind Waves

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Motivation

- $S_{ds}$ is traditionally regarded as a tuning knob
- recent experimental advances brought much more certainty into physics of whitecapping dissipation
- new physics has been revealed for the wind input term, particularly at strong winds

Little if any new experimental knowledge implemented in the models

- these physics are not a tentative reasoning, but a definite field observation
- have to be accommodated, otherwise the models do not describe reality adequately
- this is particularly relevant for complex or non-standard situations (eg. presence of swell, slanting fetches)
- the most apparent non-standard circumstance: extreme wind-wave conditions
Methodology

- to implement the newly found experimental physics for input and dissipation terms into a research model (WAVETIME, Van Vledder)

- observe known physical constraints

- tune the source functions, if necessary, separately

\[
\frac{dE(k, f, \theta, x, t)}{dt} = S_{in} + S_{ds} + S_{nl}
\]
Conclusions

- new wind input function (Donelan et al., 2006, JPO) and breaking dissipation function (Young and Babanin, 2006, JPO) have been implemented in wave research model (WAVETIME)

- approach was employed based on strict physical constraints both for the wind input and for the dissipation
  - integral of the wind input must agree with experimentally observed values of the total stress
  - integral of the wave energy dissipation must satisfy experimentally measured ratios of the total input and total dissipation

- the approach also allows investigating and fine tuning the source terms separately, before simulating the wave evolution

- Subsequent simulation of the wave evolution has been conducted

- Evolution of integral, spectral and directional properties of the wave fields is reproduced well
The approach

- Traditional approach (ie. Komen et al. (1984)): reproduce known growth curves – i.e. model the balance of the source functions rather than the functions themselves
- New approach: follows that suggested at WISE-2004 (Reading, England) by Mark Donelan
- Main constraint: integral wind momentum input must be equal to the total stress less viscous stress:

\[ \int_{0}^{\infty} S_{in}^{m}(f) df = \int_{0}^{\infty} \frac{k}{\omega} S_{in}(f) df = \tau_{w} \]

- experimental dependencies for total stress and viscous stress are used
- experimental dependencies for ratio of total input and total dissipation are used

\[ \int_{0}^{\infty} S_{ds}(f) df \leq \int_{0}^{\infty} S_{in}(f) df \]
Input and total stress

\[
\begin{align*}
\tau_w &= \tau - \tau_v \\
\tau_w &= \int_{f_{\text{min}}}^{f_{\text{cut}}} \frac{S_{\text{in}}(f')}{c(f')} df
\end{align*}
\]

\[U_{10} = 10\text{m/s} \quad F(f) - f^{-5} (\text{JONSWAP})\]
Whitecapping dissipation

- $f^{-4}$ to $f^{-5}$ transition was found based on the input integral
- now, coefficients $a$ and $b$ need to be found

$$S_{ds}(f) = a \cdot f((F(f) - F_{thr}(f))A(f)) + b \int_{f_p}^{f} (F(g) - F_{thr}(g))A(g)dg$$

- Young and Babanin $a = 0.0069$ (only one record analysed)

Donelan (1998) showing the fraction of momentum (dashed line) and of energy (plain line) retained by the waves

coeff. $a$ and $b$ based on the input/dissipation ratio
\[ \int S_{ds}(f) df < \int S_{in}(f) df \] - the physical constraint

\[ R(U_{10}/c_p) = \frac{\int S_{ds}(f) df}{\int S_{in}(f) df} \]

\[ D = \int S_{ds}(f) df \]

\[ T_1(f) = f \cdot A(f) \cdot (F(f) - F_T(f)) \]

\[ S_1 = \int T_1(f) df \quad S_{11} = \int_0^{f_p} T_1(f) df \]

\[ T_2(f) = \int f A(f) \cdot (F(f) - F_T(f)) df \]

\[ S_2 = \int T_2(f) df \]

\[ W = \int S_{in}(f) df \quad W_1 = \int_0^{f_p} S_{in}(f) df \]
Modelling the wave evolution.
Modelling the wave evolution. Directional spectra
Comparison with measurements of the breaking-crest length

\[ \Lambda(c) \left( \frac{10}{U_{10}} \right)^3 = 3.3 \times 10^{-4} e^{-0.64c} \]  Melville and Matusov, 2002

\[ S_{ds}(c) = b \rho_w g^{-1} c^5 \Lambda(c) \left( \frac{10}{U_{10}} \right)^3 \]

\[ S_{ds}(f) = \frac{g}{2\pi} \frac{1}{f^2} S_{ds}(c) \]
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