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

Alexander Babanin, Kakha Tsagareli, Ian Young, and David Walker

Swinburne University of Technology, Melbourne, Australia
The University of Adelaide, South Australia

Motivation

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

- 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

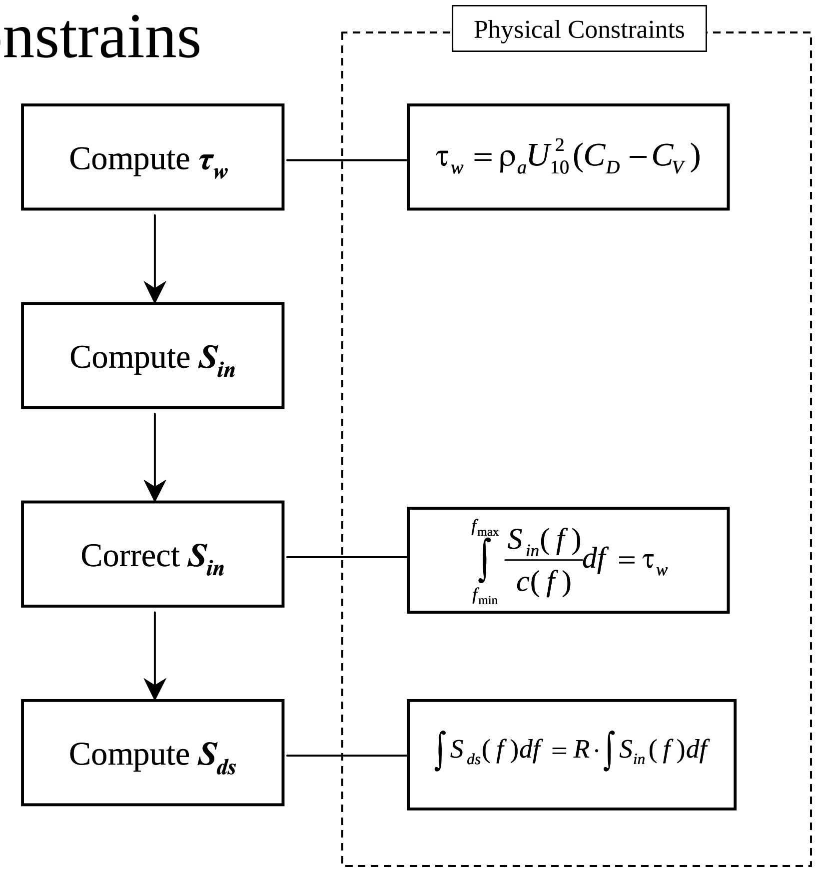
$$\frac{dE(k, f, \theta, x, t)}{dt} = S_{in} + S_{ds} + S_{nl}$$

Methodology

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

- observe known physical constrains

- tune the source functions, if necessary, separately



Conclusions

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

• 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:

$$\int_0^{f_\infty} S_{in}^m(f)df = \int_0^{f_\infty} \frac{k}{\omega} S_{in}(f)df = \tau_w$$

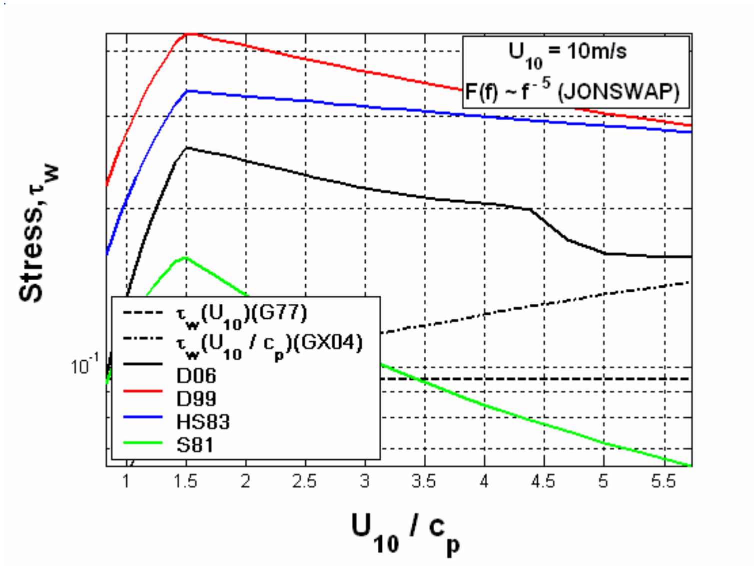
• experimental dependencies for total stress and viscous stress are used

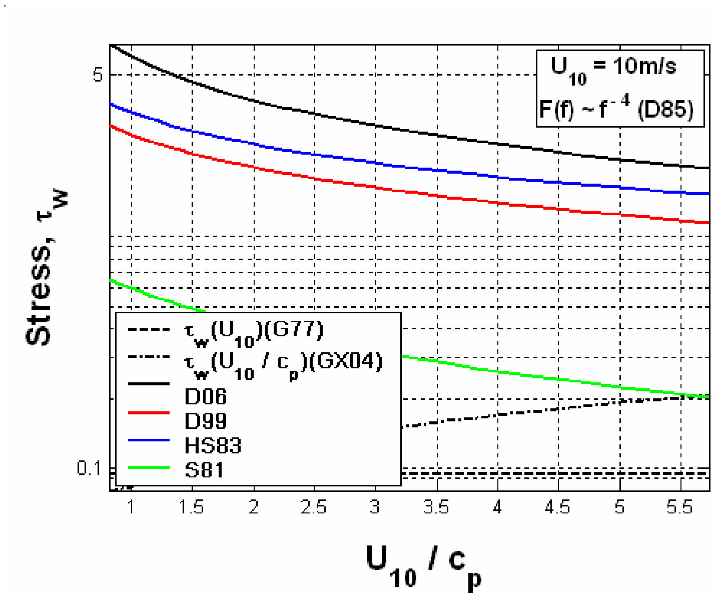
• experimental dependencies for ratio ot total input and total dissipation are used

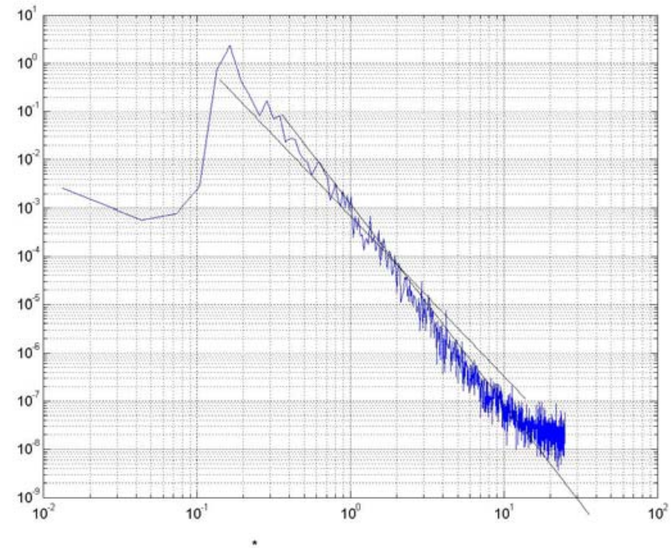
$$\int_0^{f_\infty} S_{ds}(f)df \leq \int_0^{f_\infty} S_{in}(f)df$$

Input and total stress

$$\begin{cases} \tau_w = \tau - \tau_v \\ \tau_w = \displaystyle\int_{f_{\min}}^{f_{cut}} \frac{S_{in}(f)}{c(f)} df \end{cases}$$





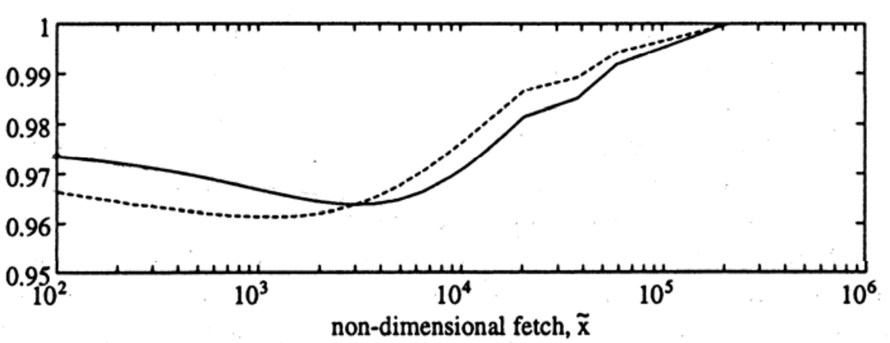


Whitecapping dissipation

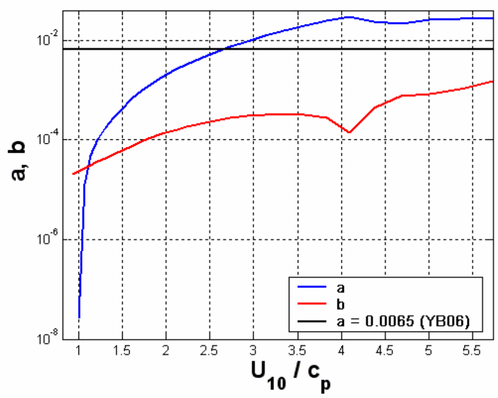
- f^{-4} to f^{-5} transition was found based on the input integral
- now, coefficients *a* and *b* need to be found

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

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



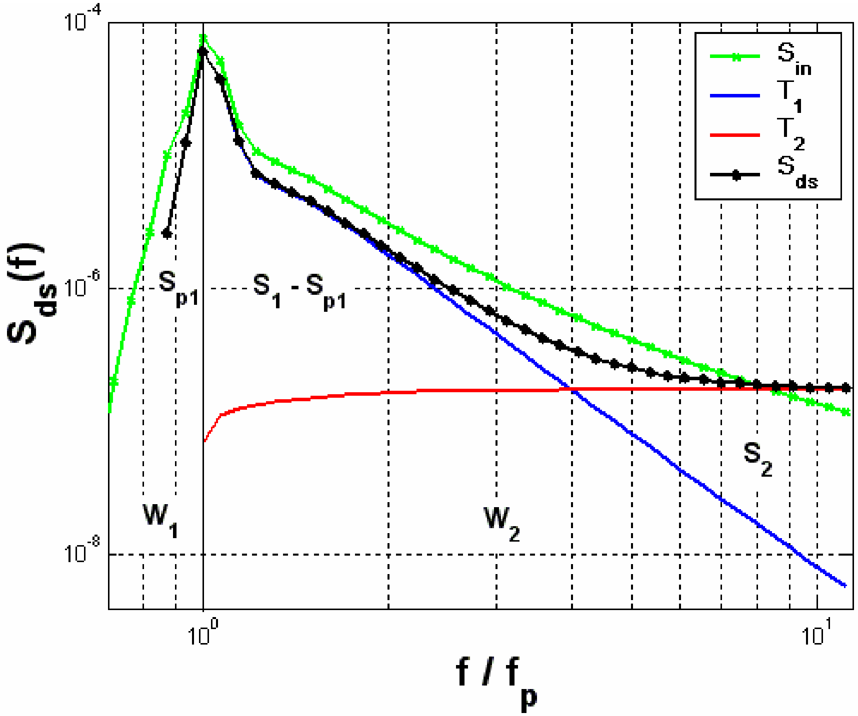
Donelan (1998) showing the fraction of momentum (dashed line) and of energy (plain line) retained by the waves



coeff. *a* and *b* based on the input/dissipation ratio

$$\int S_{ds}(f)df < \int S_{in}(f)df$$ - the physical constraint

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



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

$$T_1(f) = f \cdot A(f) \cdot (F(f) - F_T(f))$$

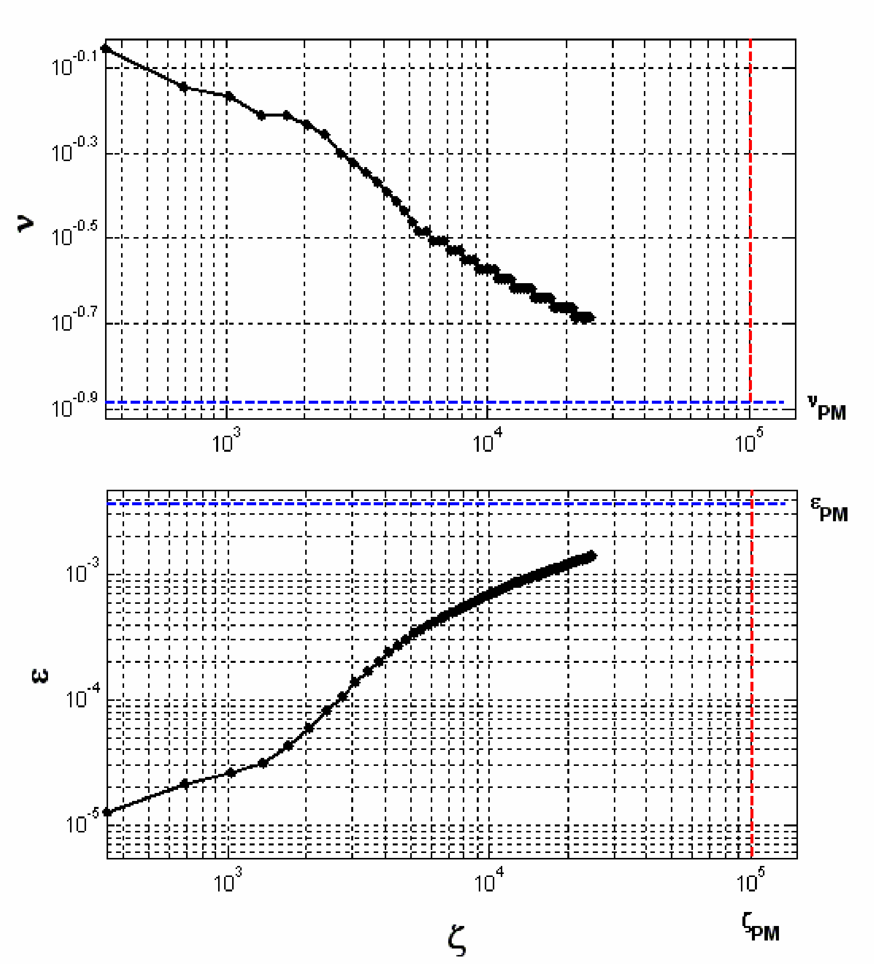
$$S_1 = \int T_1(f)df \qquad S_{11} = \int_0^{f_p} T_1(f)df$$

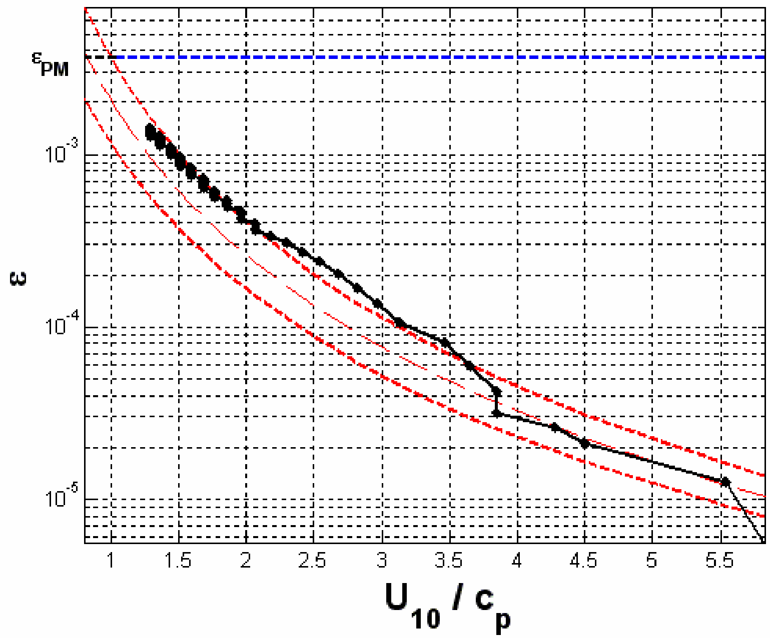
$$T_2(f) = \int_{f_p}^{f} A(f) \cdot (F(f) - F_T(f))df$$

$$S_2 = \int T_2(f)df$$

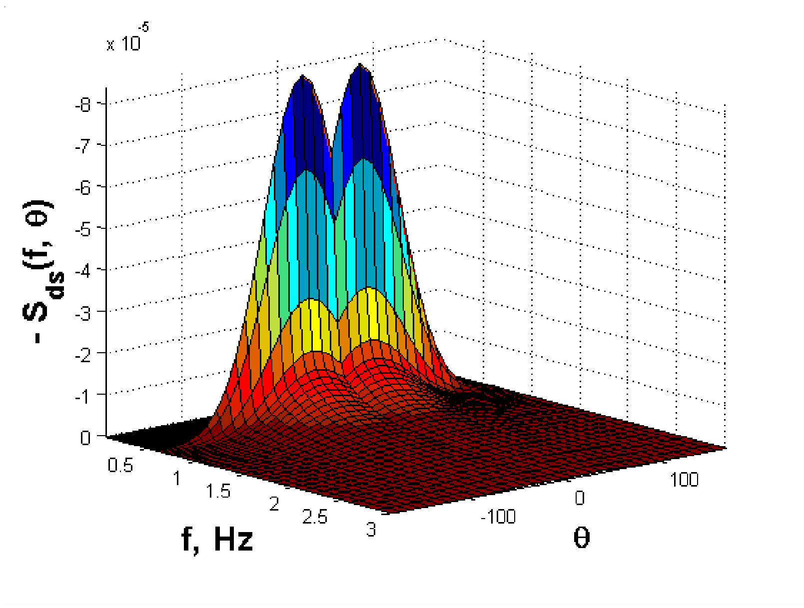
$$W = \int S_{in}(f)df \qquad W_1 = \int_0^{f_p} S_{in}(f)df$$

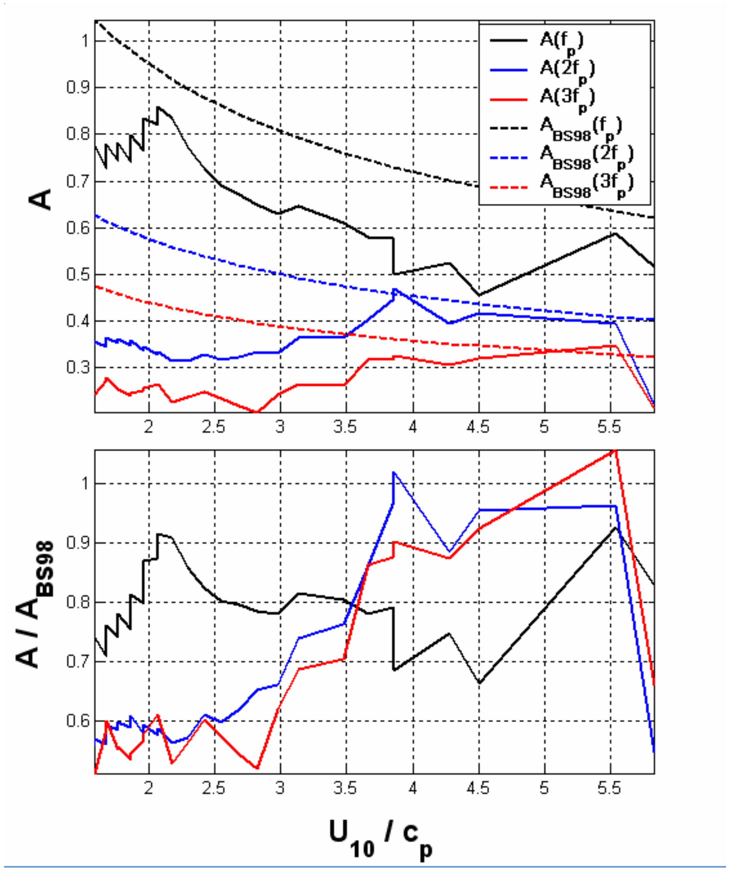
Modelling the wave evolution.





Modelling the wave evolution. Directional spectra



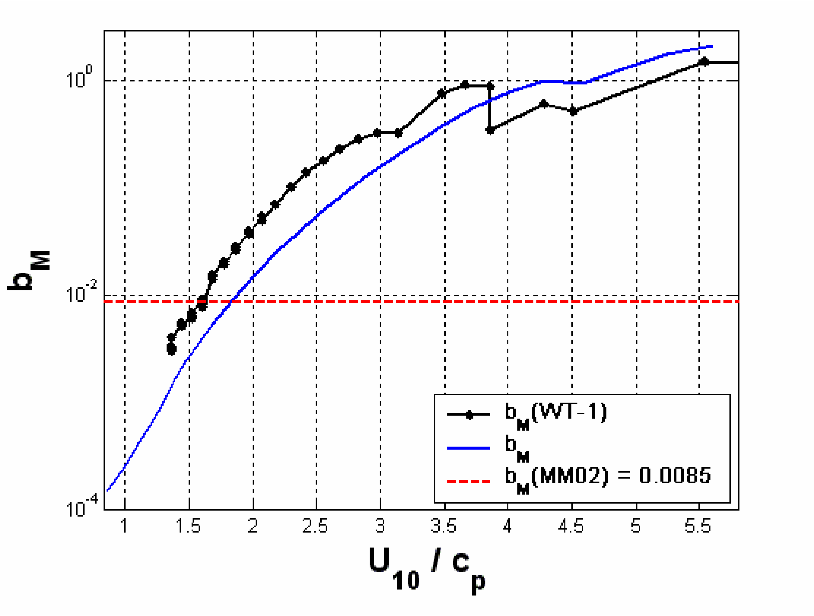


Comparison with measurements of the breaking-crest length

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

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

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



Conclusions

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

• 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