Spectral comparisons of different dissipation schemes in WAVEWATCH III™

Georgia Kalantzi, Christine Gommenginger, Meric Srokosz[1], Fabrice Ardhuin[2]

(1) National Oceanography Centre, Southampton, UK

(2) Service Hydrographique et Oceanographique de la Marine, Brest, France

Abstract

Wave breaking dissipation is one of the least understood processes implemented in wave models. Dissipation as a process plays a key role in the accurate wave forecasting in operational systems. A lot of effort has been put in the parameterization of this process, however none of these efforts has been proven to be 100% accurate both on theoretical and practical terms. In this work, WAVEWATCH III™ (version 3.14, Tolman, 2009) is used to test the three dissipation formulations that it includes: i.e., i) the WAM-3 (Komen *et al.*, 1994) (**WAM3**), ii) the Tolman & Chalikov (1996) (**TC96**) and iii) the WAM-4 (Janssen, 1994) which includes Bidlot *et al.*, (2005) (**BAJ**) and Ardhuin *et al.*, (2009) (**ACC405**) alterations, along with the herewith implemented in the model Babanin *et al.*, (2007) (**BAB**) dissipation term. The dissipation spectral shapes of these terms were compared for simple one-point test cases under controlled initial conditions. The results give insight to the way these dissipation formulations 'work' and the way they respond to different initial wind and wave fields. Moreover, they open way to further work on the implementation of physically consistent dissipation terms into contemporary wave models.

Babanin et al., 2007 dissipation term

Babanin et al. (2007) conducted an experimental study of wave energy dissipation, which allowed simultaneous measurements of the source functions in a broad range of conditions. They measured directly the spectral dissipation and they derived frequency distributions both for the wave breaking probability and the breaking severity. They demonstrated that the breaking of waves at a particular frequency causes energy damping in a broad spectral band above that frequency and thus causes a cumulative dissipative effect for waves of smaller scales. At these high frequencies, the cumulative dissipation appears to dominate compared to inherent wave-breaking dissipation. Moreover, they found that at moderate winds the dissipation is fully determined by the wave spectrum whereas at strong winds it is also a function of the wind speed. This result indicates that at extreme wind-forcing conditions a significant part of the extra energy flux is dissipated locally rather than being available for enhancing the wave growth.

$$S_{ds}(f) = -a_1 f\left[\left(F(f) - F_{thr}(f)\right)A(f)\right]^n - a_2\int_{f_p}^{f}\left[\left(F(q) - F_{thr}(q)\right)A(q)\right]^n dq$$

a_i constants, $A(f)$ integral characteristic of the inverse directional spectral width,

$$E_{thr}(f) = 2g^2\sigma_{thr}/(2\pi)^4 A(f) f^5, \quad \sqrt{\sigma_{thr}} = 0.035$$

The approach

- As a start we implemented Babanin *et al.*, (2007) dissipation term into the model and paired it with the wind input of Tolman and Chalikov (1996).
- Each dissipation scheme was then tested in simple test runs at one grid point with idealized wind and wave forcing for each run; here we only show results for wind speed of 10 m/sec, and initial wave height of 0 and 3 m.
- The initial field type was Gaussian in frequency and space, and cosine type in direction, while the runs were set up for 30 frequencies from 0.0412 to 0.6530, and 36 directions.
- The initial wave field's direction was set to 90o and the wind's direction to 270, so as to achieve maximum dissipation. The duration of the model runs was 96 hours.

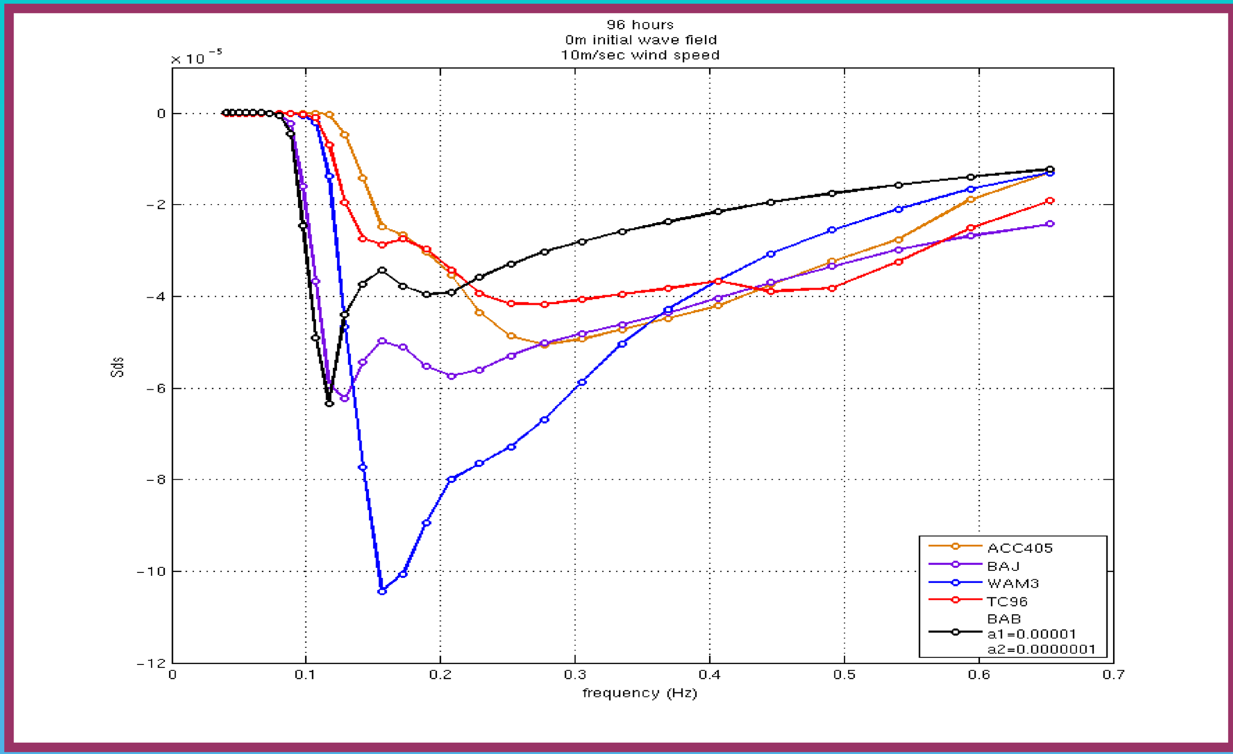

Figure 1a: One-dimensional dissipation spectra for the source terms examined, plotted against frequency, at 96 hours. The plot corresponds to 0 m initial wave field and 10 m/sec wind speed.

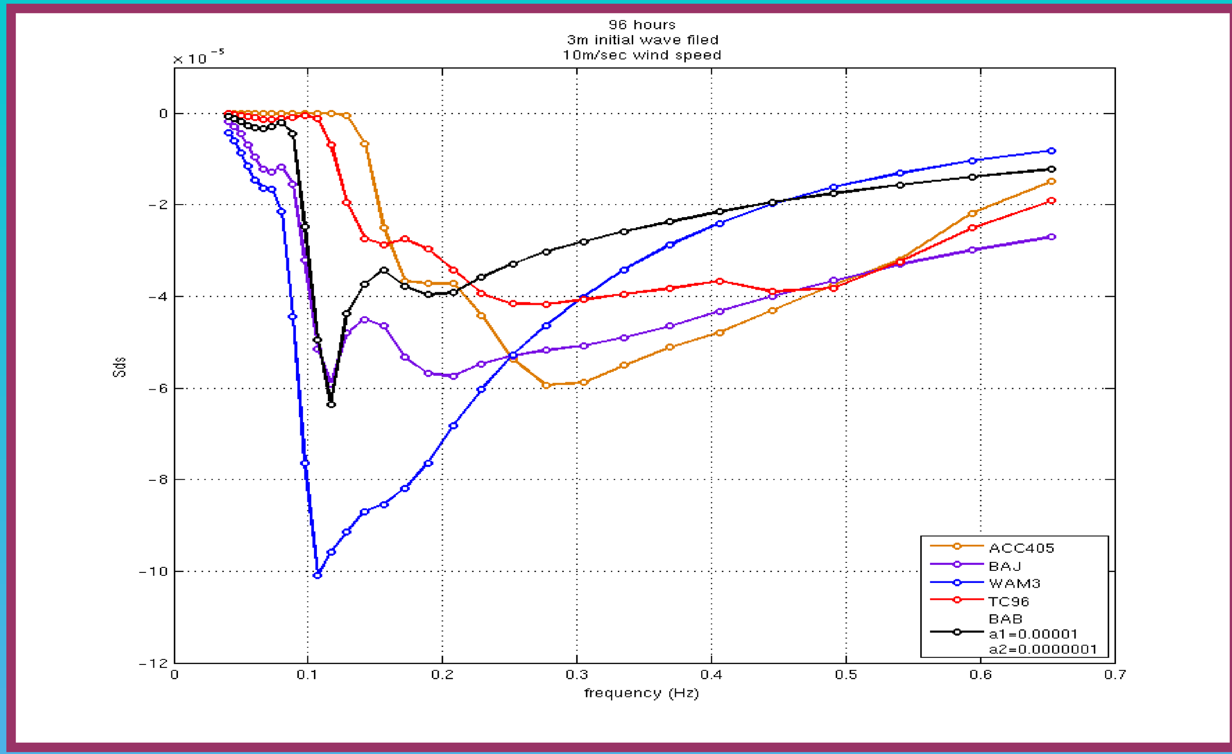

Figure 2a: One-dimensional dissipation spectra for the source terms examined plotted against f/f_p, at 96 hours. The plot corresponds to 0 m initial wave field and 10 m/sec wind speed.

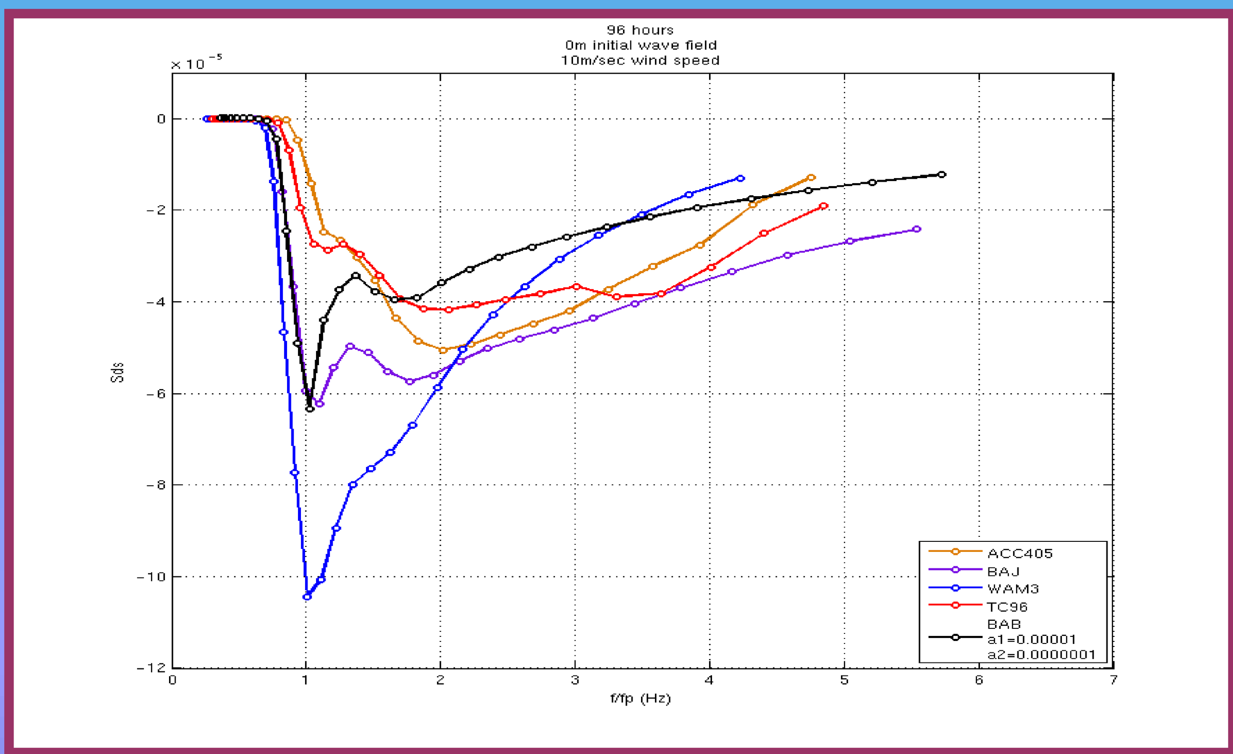

Figure 1b: One-dimensional dissipation spectra for the source terms examined, plotted against frequency, at 96 hours. The plot corresponds to 3 m initial wave field and 10 m/sec wind speed.

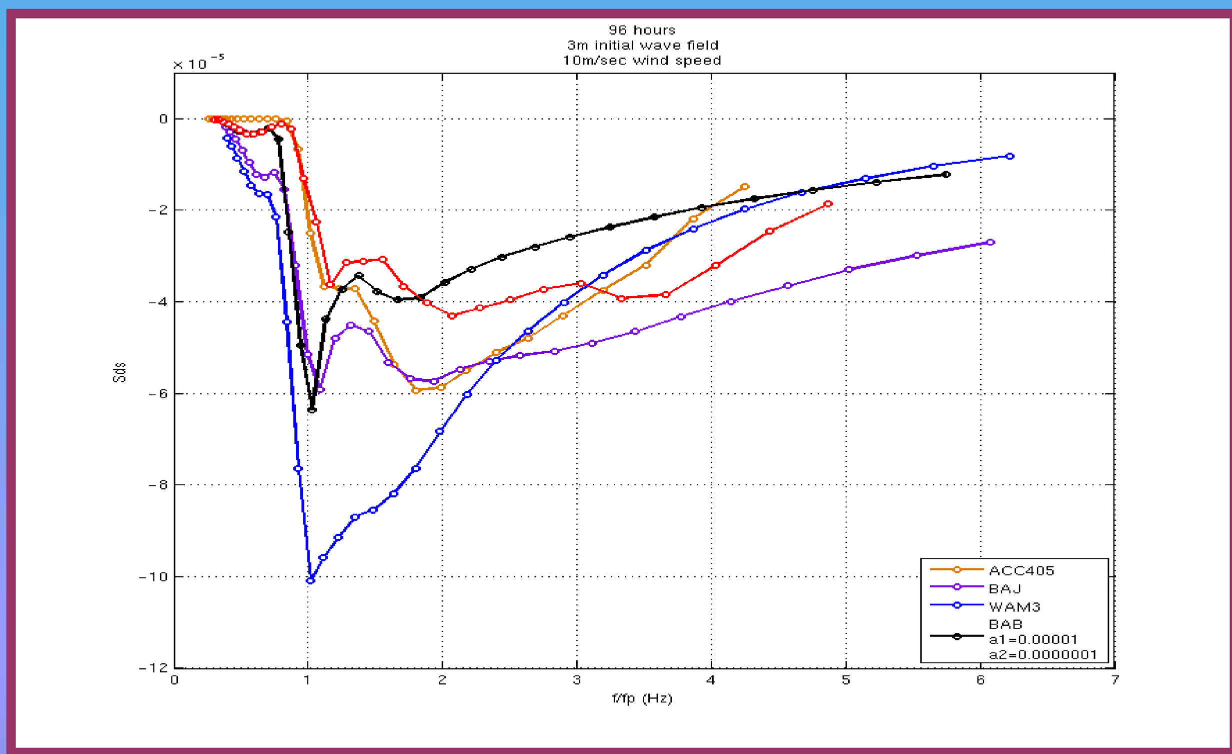

Figure 2b: One-dimensional dissipation spectra for the source terms examined plotted against *f/fp*, at 96 hours. The plot corresponds to 3 m initial wave field and 10 m/sec wind speed.

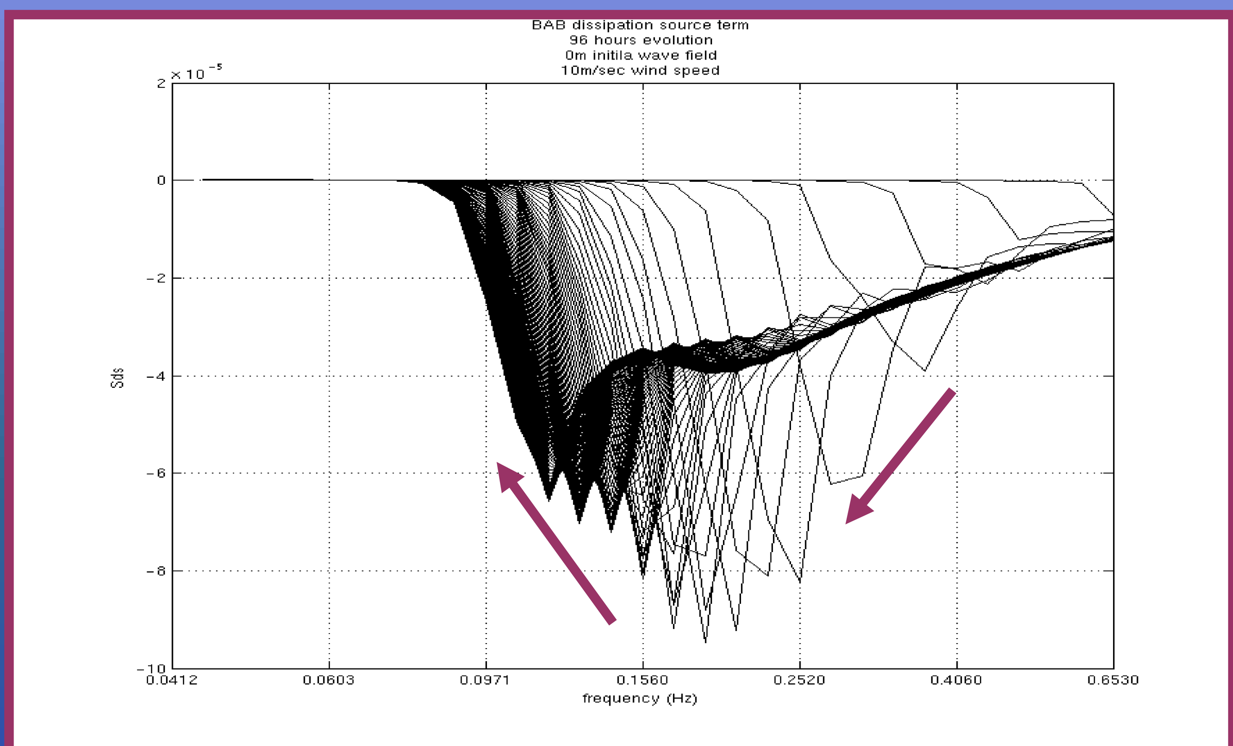

Figure 3a: Evolution of the one-dimensional dissipation spectra of BAB term from zero time to 96 hours. The spectra are plotted against frequency and the time evolution progresses from the lower to the higher line density (arrows). The plot corresponds to 0 m initial wave field and 10 m/sec wind speed.

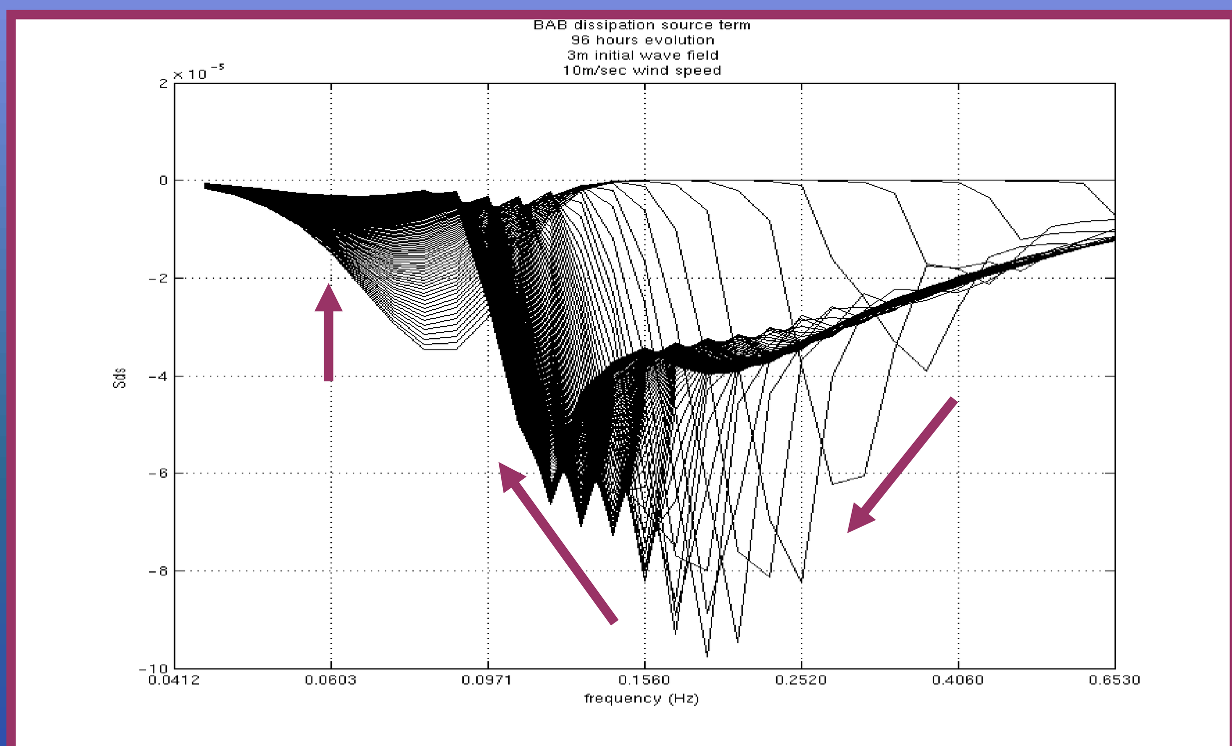

Figure 3b: Evolution of the one-dimensional dissipation spectra of BAB term from zero time to 96 hours. The spectra are plotted against frequency and the time evolution progresses from the lower to the higher line density (arrows). The plot corresponds to 3 m initial wave field and 10 m/sec wind speed.

Results and Comments

For each run and each dissipation term, we examined the 1-D dissipation spectra and we plot the results for a specific combination of initial wave field and wind speed with respect to frequency or *f/fp*. Also we present the evolution of the 1-D dissipation spectra for Babanin *et al*. (2007) term, from zero time up to 96 hours, for the two combinations of initial wave field and wind speed. We chose to show both type of plots, since frequency on the X axis gives information on which frequency each dissipation maximum is located, while when *f/fp* is on the X axis the dissipation spectra are compared on common ground against multiples of f_p.

From the dissipation spectral comparisons it seems that BAB presents similar shape to BAJ, although producing less dissipation for frequencies higher than the peak frequency. Different from those two but quite similar to each other are the shapes of the dissipation spectra of ACC405 and TC96. WAM3 produced dissipation spectral shapes that were very different from all other terms.

Since the majority of modeled dissipation terms are parameterized as "tuning knobs" to simply close the wave energy balance, we aimed to test a completely independent source term in the model. Despite the luck of any previous tuning, Babanin *et al*. (2007) dissipation term gave quite comparable results to all other extensively tuned in the model, terms.

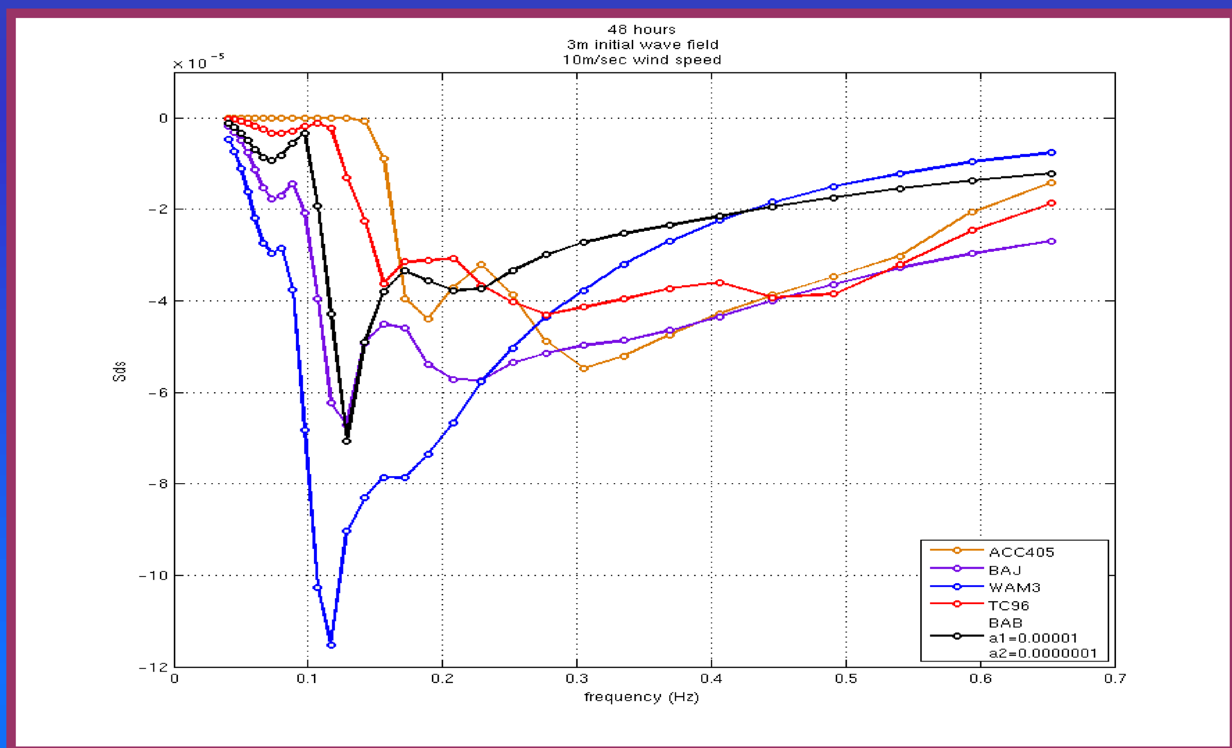

Figure 4: One-dimensional dissipation spectra of the source terms examined plotted against frequency, 48 hours. The plot corresponds to 3 m initial wave field and 10 m/sec wind speed.

References

Ardhuin, F., E. Rogers, A. Babanin, J-F. Filipot, R. Magne, A. Roland, A. van der Westhuysen, P. Queffeulou, J-M. Lefevre, L. Aouf, F. Collard, 2009: Semi-empirical dissipation source functions for ocean waves: Part I, definition, calibration and validation. *J. Phys. Ocean*, in press.

Babanin, A., K., Tsagareli, I. R., Young, D., Walker, 2007b: Implementation of new experimental input/dissipation terms for modelling spectral evolution of wind-waves, Proc. 10th Int. Workshop on Wave Hindcasting and Forecasting 2007, 11-16 November, Oahu, Hawaii, USA.

Bidlot, J. R., S., Abdalla, P. A. E. M., Janssen, 2005: A revised formulation for ocean wave dissipation in CY25R1. Tech. Rep. Memorandum R60.9/JB/0516, Research Department, ECMWF, Reading, U.K.

Janssen, P.A.E.M., K. Hasselmann, S. Hasselmann, and G. J. Komen, 1994: Parameterization of source terms and the energy balance in a growing wind sea. Dynamics and modelling of ocean waves, G. J. Komen et al., ed., Cambridge University Press, pages 215– 238.

Komen, GJ, Cavaleri, L, Donelan, M, Hasselmann, K, Hasselmann, S, Janssen, PAEM (1994). "Dynamics and Modelling of Ocean Waves". Cambridge University Press, ISBN: 0-521-47047-1. Cambridge, Great Britain.

Tolman, HL 2009: User manual and system documentation of WAVEWATCH-III version 3.14. NOAA / NWS / NCEP / OMB Technical Note, No. 276, 194 pp.

Tolman, HL, Chalikov, DV, 1996. "Source terms in a third generation wind-wave model". *Journal of Physical Oceanography*, 26, pp. 2497-2518.

National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL