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Source term parameterization of unresolved obstacles in wave modelling

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In the present work we introduce two source terms for the parameterization of energy dissipation due to unresolved obstacles in spectral wave models. The proposed approach differs from the classical one based on spatial propagation schemes because it provides a local representation of phenomena such as unresolved wave energy dissipation. This source term-based approach presents the advantage of decoupling the parameterization of unresolved obstacles from the spatial propagation scheme. Furthermore it opens the way to parameterizations of other unresolved sheltering effects like rotation and frequency shift of spectral components. Energy dissipation due to unresolved obstacles is modeled locally through a Local Dissipation (LD) source term in order to provide a low resolution obstructed cell for the correct average energy. Furthermore a Shadow Effect (SE) source term has been introduced to model the correct energy flux towards downstream cells. The LD-SE scheme source term aims to reproduce in a low resolution grid the average conditions modeled by a high resolution model able to resolve obstacles in an exact way. The LD and SE source terms are expressed as functions of obstructed cell transparency coefficients relative to different spectral components. An interesting finding is that an overall transparency coefficient α for each cell/spectral component is not enough to model adequately the average conditions. A further coefficient β is needed to take into account the layout of the obstacles inside the cell. This coefficient is given by the average transparency of sections starting from the upstream side of the obstructed cell. The mono-dimensional LD and SE source terms are given by:

$$\left.\frac{\partial F}{\partial t}\right|_{LD} = -\frac{1-\alpha_l}{\beta_l}\frac{c_g}{\Delta x}F \tag{1}$$

$$\left.\frac{\partial F}{\partial t}\right|_{SE} = -\left(1-\frac{\beta_u}{\alpha_u}\right)\frac{c_g}{\Delta x}F \tag{2}$$

where "l" and "u" subscripts indicate that α and β coefficients are relative to local and upstream cells respectively. Validation of the source terms has been carried out on six synthetic case studies, showing their ability to describe the average energy dissipation in a way close to high resolution models able to resolve exactly the obstacles. In four of the six case studies the source term approach performs better than the standard approach of WWIII based on the propagation scheme ([**?**]), and in another case study the overall performances of the two approaches are very close. In the remaining case study, representing conditions of strong dissipation close to the upstream side of the cell, the results provided by the LD-SE scheme are reasonable, but worse than those provided by the traditional approach. An interesting approach for the computation of α and β coefficients might be the employment of high resolution stationary wave models initialized with different sets of boundary conditions like monochromatic waves or other elementary wave packages. Such a methodology could provide diagnostic responses of unresolved obstacles throughout the whole spectral space, allowing a more accurate estimation of α and β as function not only of spectral component direction, but also of spectral component frequency. Moreover it could allow to evaluate additional coefficients useful to parameterize unresolved rotation and frequency shift effects.

References

[1] Chawla, A., Tolman, H. L., 2008. Obstruction grids for spectral wave models. Ocean Modelling 22 (22), 12–25.