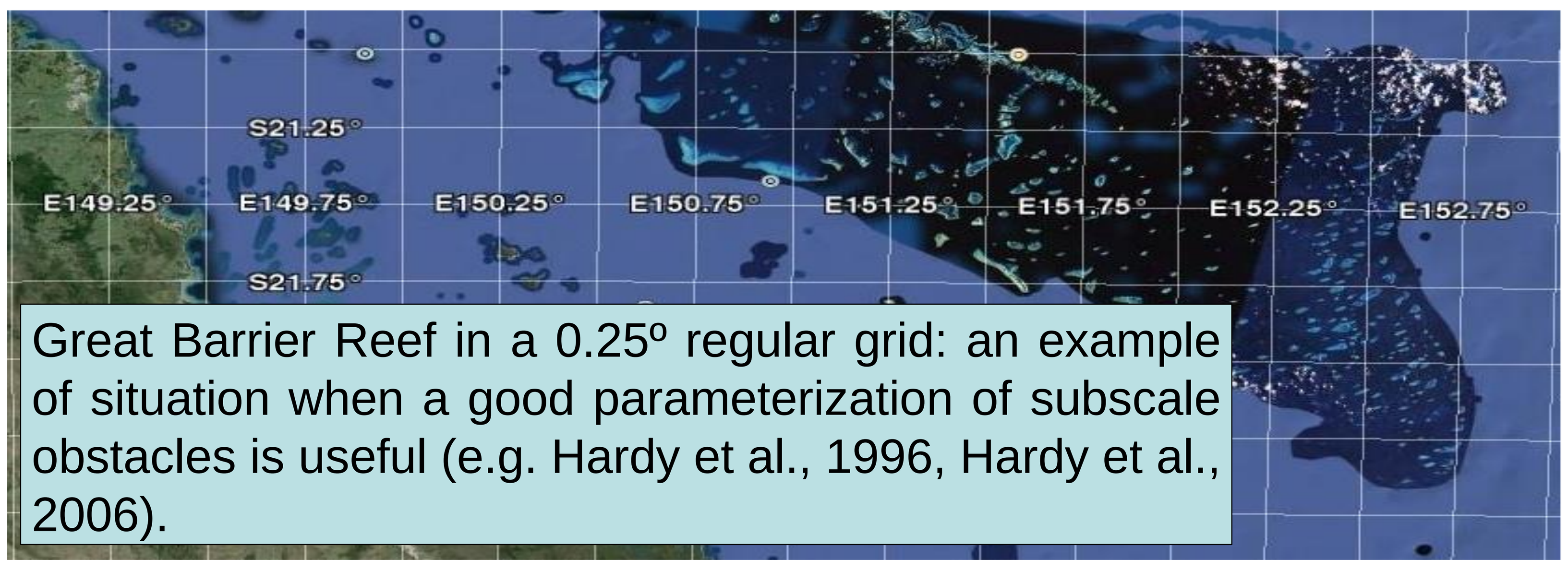
Parameterization of unresolved obstacles in wave modeling: a source term approach

L. Mentaschi [a], J. Pérez [b], G. Besio [a], F.J. Mendez [b], M. Menendez [b]

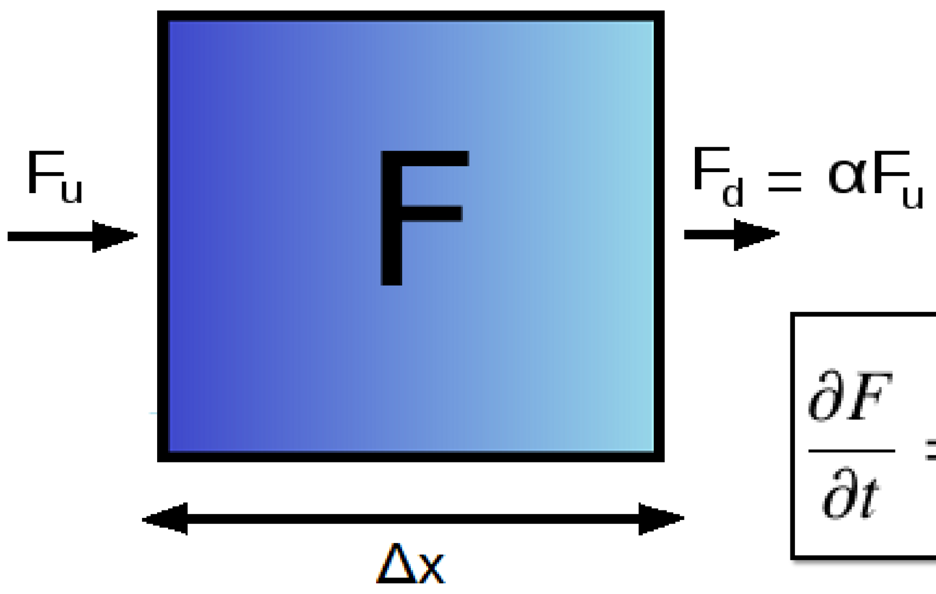
[a] DICCA, Dipartimento di Ingegneria Civile, Chimica e Ambientale, Univ. di Genova, lorenzo.mentaschi@unige.it
[b] IHC, Instituto de Hidraulica Ambiental de la Universidad de Cantabria PCTCAN C/Isabel Torres 15, 39011 Santander, Spain

Introduction

In this work we introduce two source terms for the parameterization of energy dissipation due to unresolved obstacles in spectral wave models. This new approach improves unresolved obstacles parameterization thanks to a representation of local phenomena like unresolved energy dissipation in a more localized way than methods based on spatial propagation schemes. Furthermore this source term-based approach can be applied to unstructured grids and may open the way to parameterizations of other unresolved effects like rotation and frequency shift of spectral components.



Great Barrier Reef in a 0.25º regular grid: an example of situation when a good parameterization of subscale obstacles is useful (e.g. Hardy et al., 1996, Hardy et al., 2006).



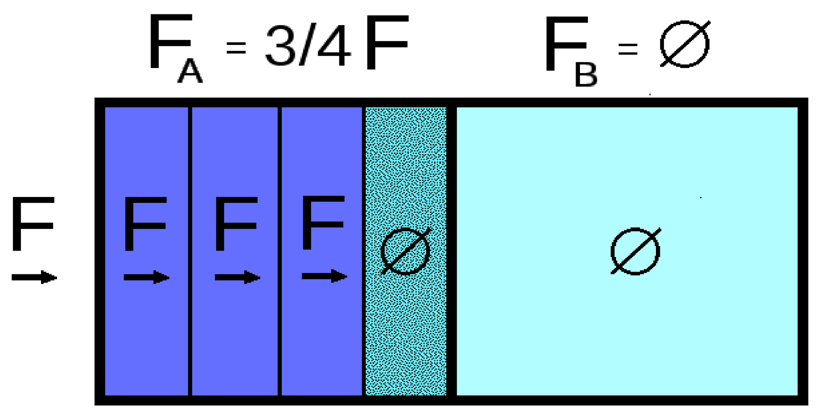
Local source term

Models local dissipation. It is conceived to provide a low resolution cell for the correct average energy.

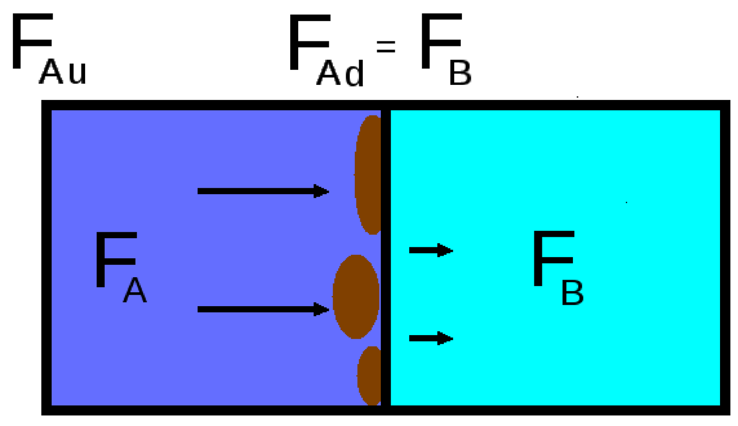
$$\frac{\partial F}{\partial t} = -\frac{1-\alpha}{\beta}\sqrt{\left(\frac{c_{gx}}{\Delta x}\right)^2+\left(\frac{c_{gy}}{\Delta y}\right)^2}\,F$$

α: overall cell transparency coefficient to the considered spectral component.

β: average transparency of cell sections starting from the cell upstream side.



Example of shadow: energy is totally blocked between the upstream cell and the downstream cell, and no energy enters the down-stream cell.



Example of shadow: obstacles at the border between cells A and B project their shadow towards cell B.

Shadow source term

Models the shadow of the obstructed cell towards the downstream cells.

Monodimensional source term

$$\frac{\partial F}{\partial t} = -\psi(v)\frac{c_g}{\Delta x}\left(\frac{\beta_u}{\alpha_u}-1\right)F$$

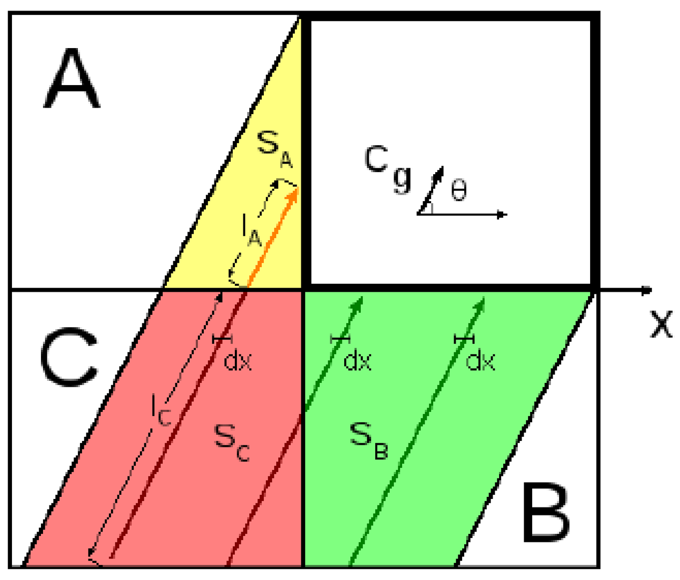
ψ(v): decreasing function of wave age to reduce the shadow of locally generated spectral components, $0 \le \psi \le 1$.

α_u: α coefficient of the upstream cell.

β_u: β coefficient of the upstream cell.

Bidimensional source term

$$\frac{\partial F}{\partial t} = -\mathbf{C}\left[K_A\left(\frac{\beta_A}{\alpha_A}-1\right)+K_B\left(\frac{\beta_B}{\alpha_B}-1\right)+K_C\left(\frac{\beta_C}{\alpha_C}-1\right)\right]$$



$$\mathbf{C} = \psi(v)\sqrt{\left(\frac{c_{gx}}{\Delta x}\right)^2+\left(\frac{c_{gy}}{\Delta y}\right)^2}$$

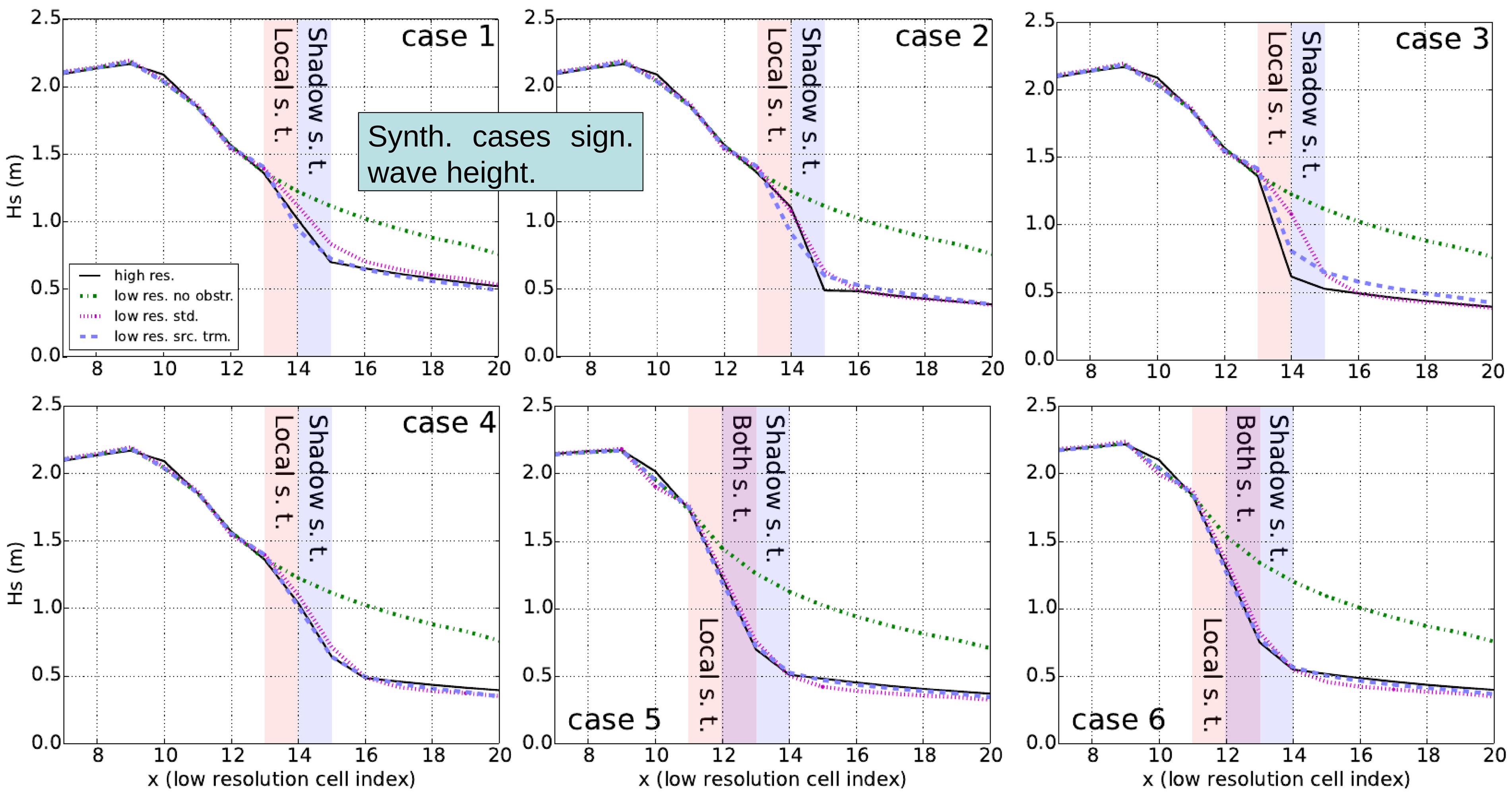
$$K_A = \frac{S_A}{S_A+S_B+S_C}$$

$$K_B = \frac{S_B}{S_A+S_B+S_C}$$

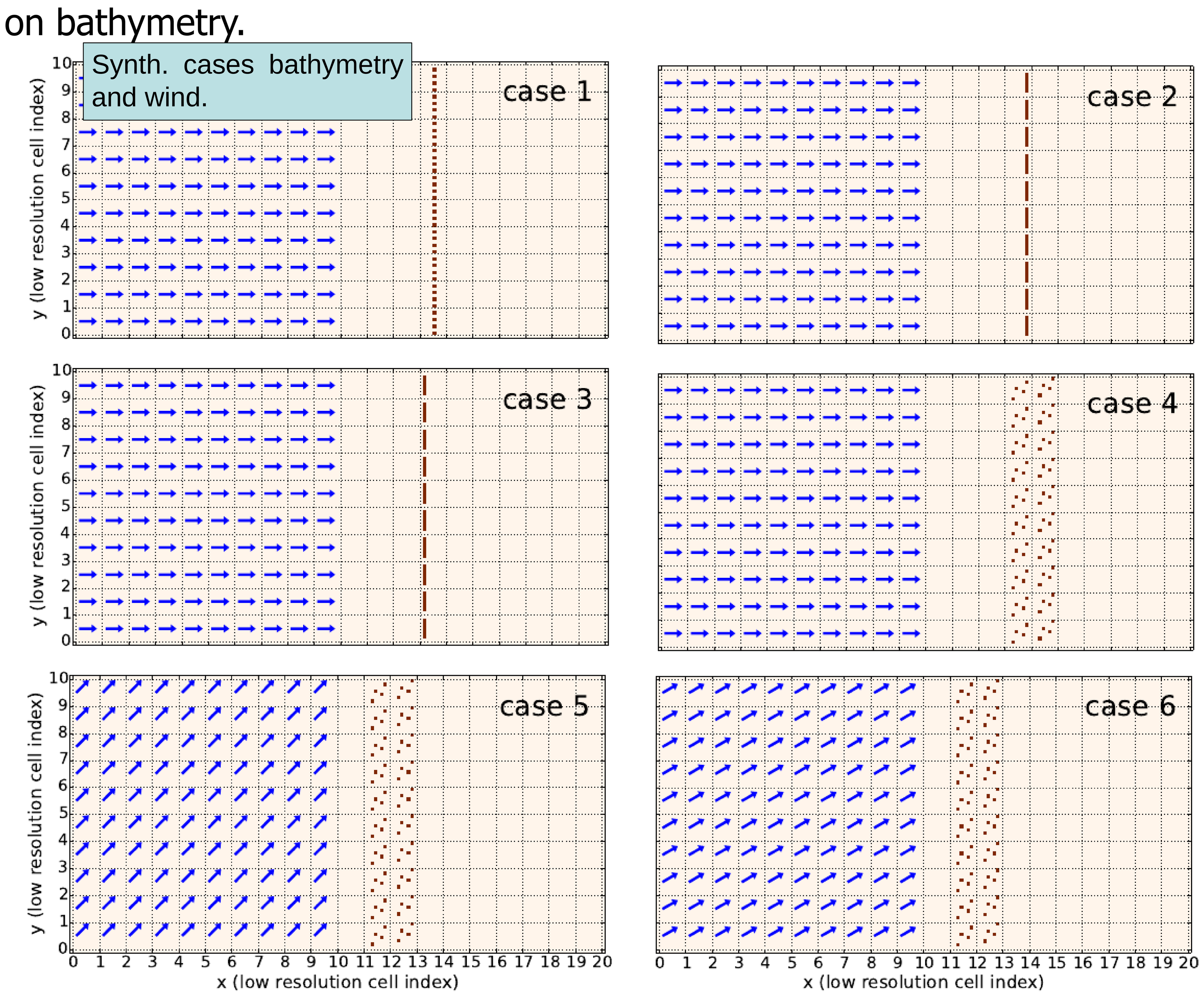
$$K_C = \frac{S_C}{S_A+S_B+S_C}$$

Theory validation: some synthetic cases

The source terms have been validated on a set of six theoretical case studies using WWIII model. For each case study a synthetic high resolution constant bathymetry (500 m deep) has been generated on a regular grid 160x80 with a resolution of 0.1º, with isolated dry points (or small groups of dry points) representing small islands. A corresponding low resolution grid 20x10 have been constructed with a resolution of 0.8º. Side size of low resolution cells is eight times the side size of high resolution ones, so that the effect of "small islands" is resolved in the high resolution run, while in low resolution runs it is parameterized by the source terms. Alpha and beta coefficients have been estimated on the basis of geometrical considerations on bathymetry.



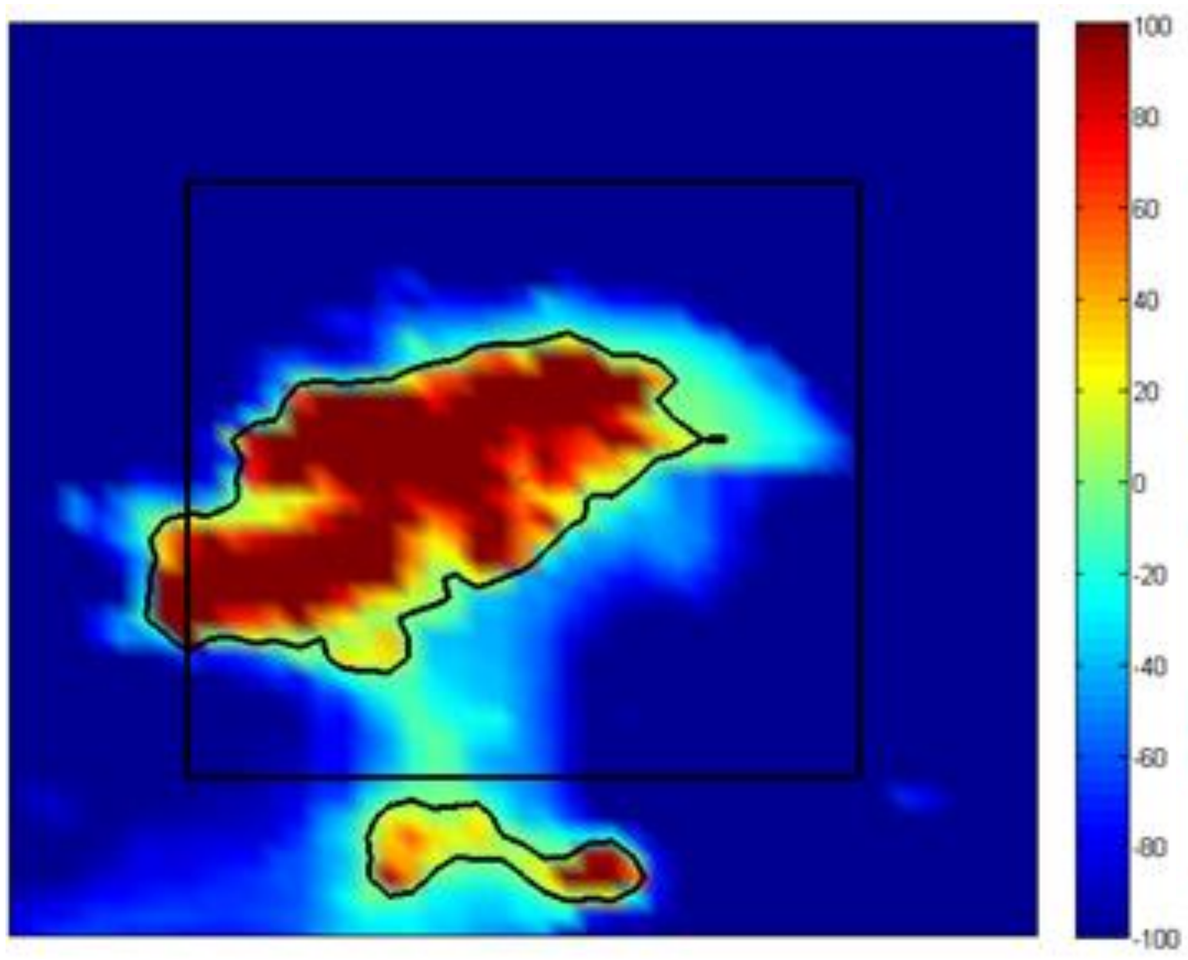
Synth. cases sign. wave height.

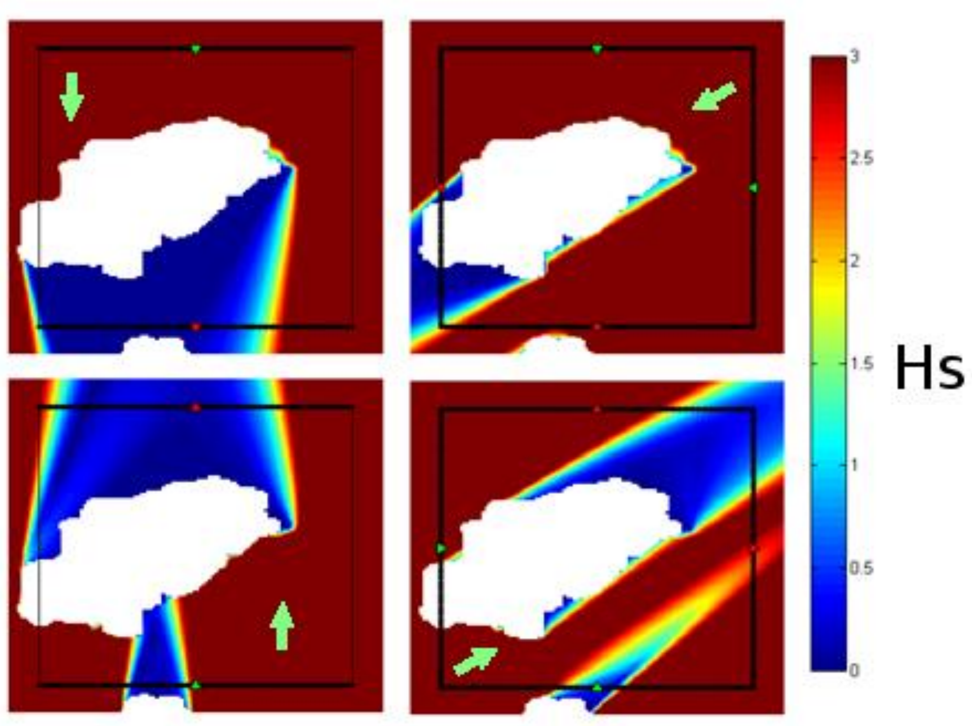


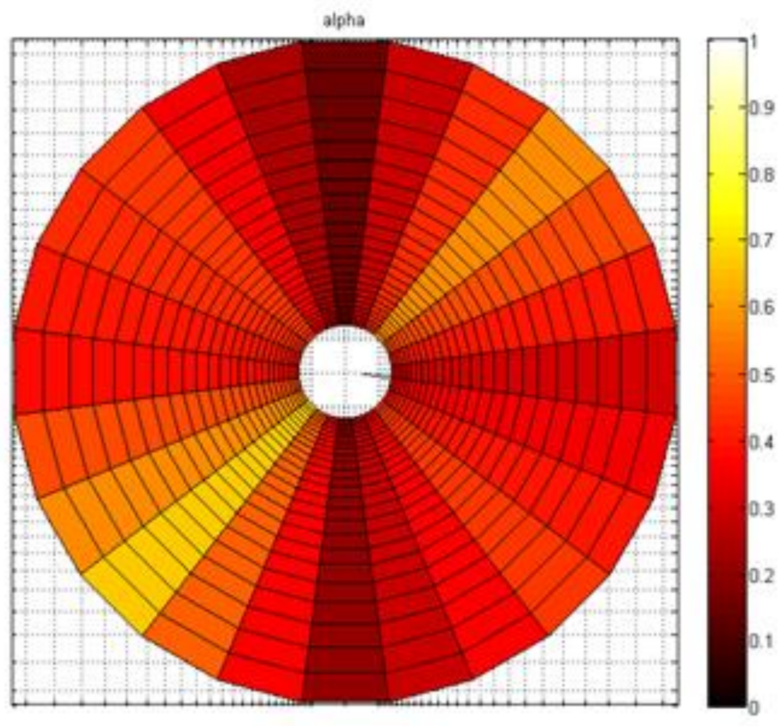
Synth. cases bathymetry and wind.

A new idea to compute α and β coefficients

Estimation of α and β coefficients is usually accomplished on the basis of geometrical considerations on subscale obstacles layout (e.g. Tolman, 2003; Chawla and Tolman, 2008; Hardy et al., 2000). An alternate approach might be the employment of high resolution stationary wave models using monochromatic waves or other elementary wave packages as boundary condition. Such a method could provide diagnostic responses of unresolved obstacles throughout the whole spectral space. Moreover it could allow to evaluate additional coefficients useful to parameterize unresolved rotation and frequency shift effects.







This research has been funded by Università degli Studi di Genova through the Progetto di Ricerca di Ateno 2014

Bibliography

Chawla A. & Tolman H.L. (2008), Obstruction grids for spectral wave models. *Ocean Modelling*, 22, 12-25.
Hardy, T. A., & Young, I. R., (1996), Field study of wave attenuation on an offshore coral reef, *Journal of Geophysical research*, 14 (101), 301-326.
Hardy, T. A., Mason, B. L. & McConochie, J. D., (2006). A wave model for the great barrier reef. *Ocean Engineering 28*, 45-70.
Tolman, H.L., 2003. Treatment of unresolved islands and ice in wind wave models. *Ocean Modelling* 5, 219-231.