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Source term parameterization of unresolved obstacles in wave modelling: work in progress

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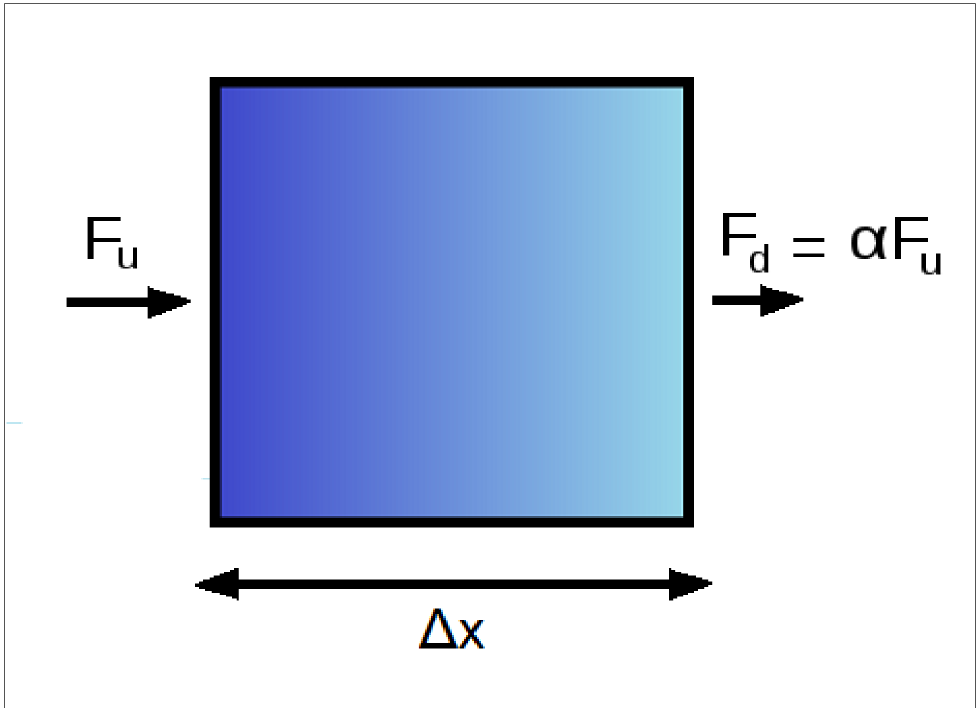
Traditional approach based on the propagation scheme

(Booj et al. 1999, Holthuijsen et al., 2001, Tolman, 2003, Bidlot 2012, Chawla & Tolman, 2008)

- definition of transparency coefficients along the grid axis α_x and α_y .
- consequent reduction of the energy fluxes:

$$F_{xd} = \alpha_x F_{xu}$$

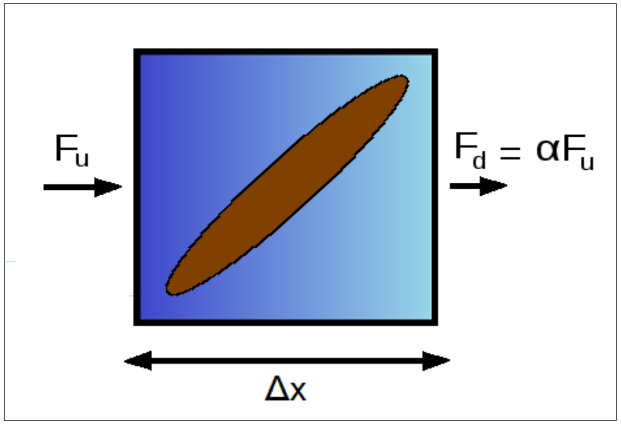
$$F_{yd} = \alpha_y F_{yu}$$



WWIII: Gridgen package (Chawla 2007): automatic estimation of the transparency coefficients.

Major drawback of the traditional approach:

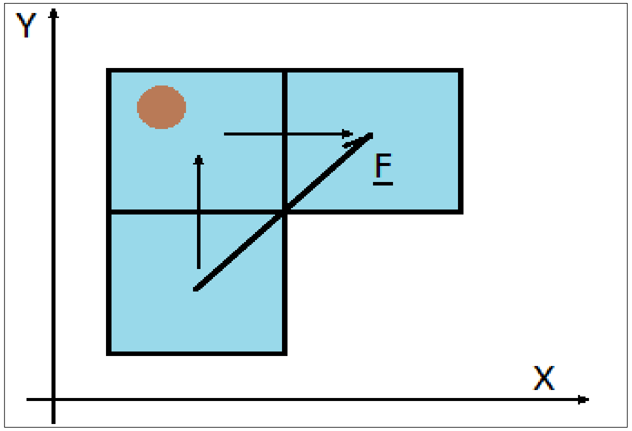
- the parameterization is inside the propagation scheme. It should be re-implemented and re-tested for every propagation scheme;
- it is unsupported in unstructured grids.



Minor drawbacks:

- In WWIII, couple of α for one cell is sometimes not enough and a modulation of α with direction (and frequency) would improve the results (Hardy et al. 2000).

- Non local representation of mainly local phenomena like energy dissipation.



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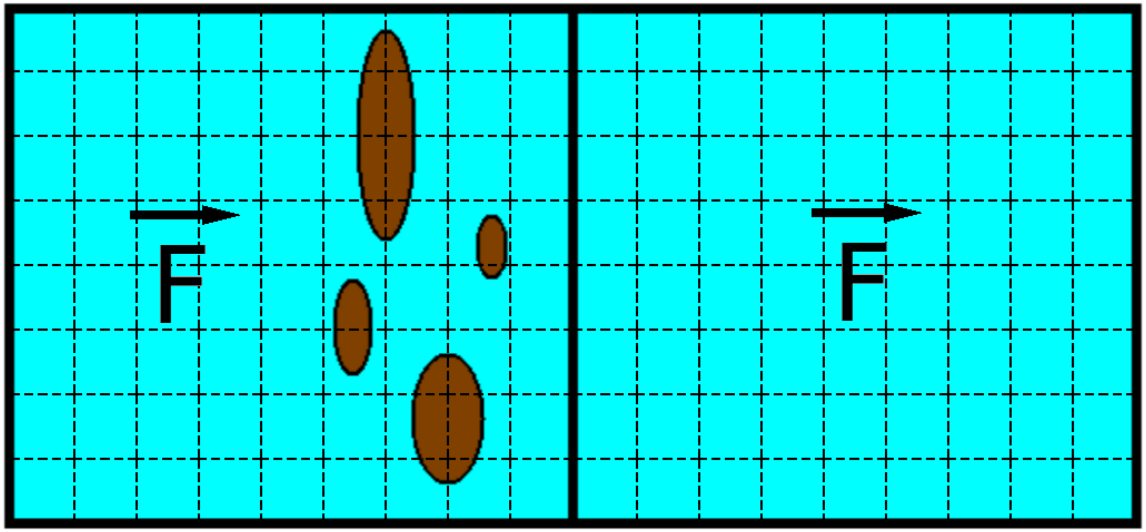
Source term approach

It solves the major drawback, and improves the minor ones.

(Mentaschi L., Perez J., Besio G., Mendez F. & Menendez M. 2015, Ocean Modelling).

Theoretical hypothesis: we can reproduce in a low resolution model what happens in the average in a high resolution model.

Local Dissipation s.t.:
parameterization of the average effects of the unresolved obstacles on the cell where they are located.



Shadow Effect s.t.:
Parameterization of the average effects on the downstream cell.

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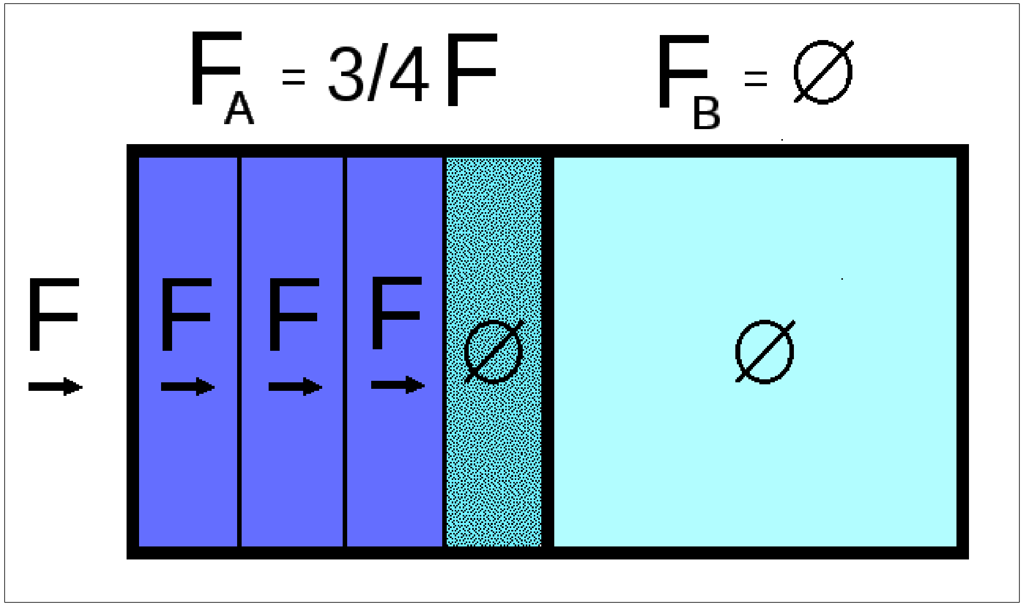
Like in the traditional approach we rely on the concept of transparency, but …

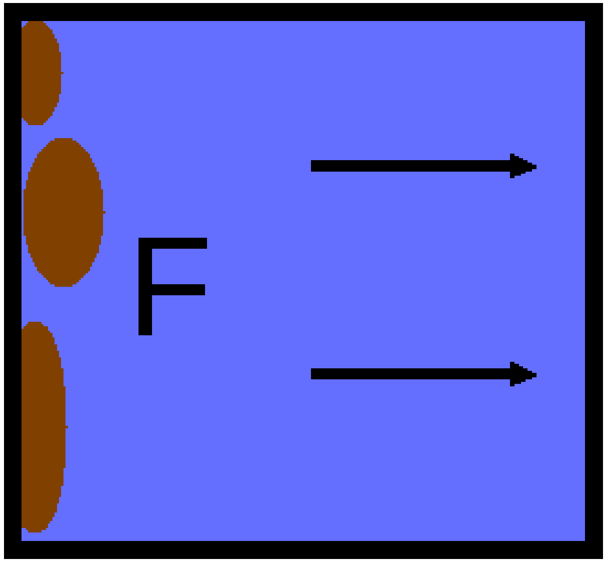
a single transparency coefficient α for each cell/spectral component is not enough.



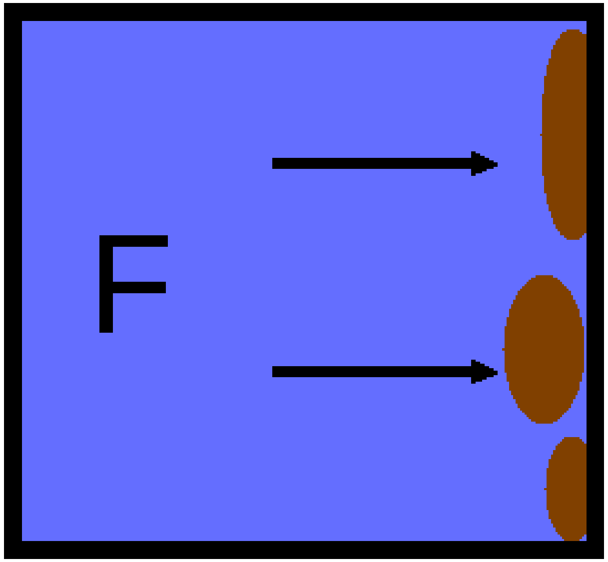
Coefficient β: average transparency of all the subsections of the cell starting from the upstream side.

The value of the coefficient beta is a function of the layout of the unresolved obstacles inside the cell.

β ≈ α: all the unresolved obstacles are close to the upstream side.



β ≈ 1: all the unresolved obstacles are close to the downstream side. Their effect on the local cell is small.



Local Dissipation s.t. :

$$\left.\frac{\partial F}{\partial t}\right|_{LD} = -D\frac{1-\beta}{\beta}F$$

Shadow Effect s.t. :

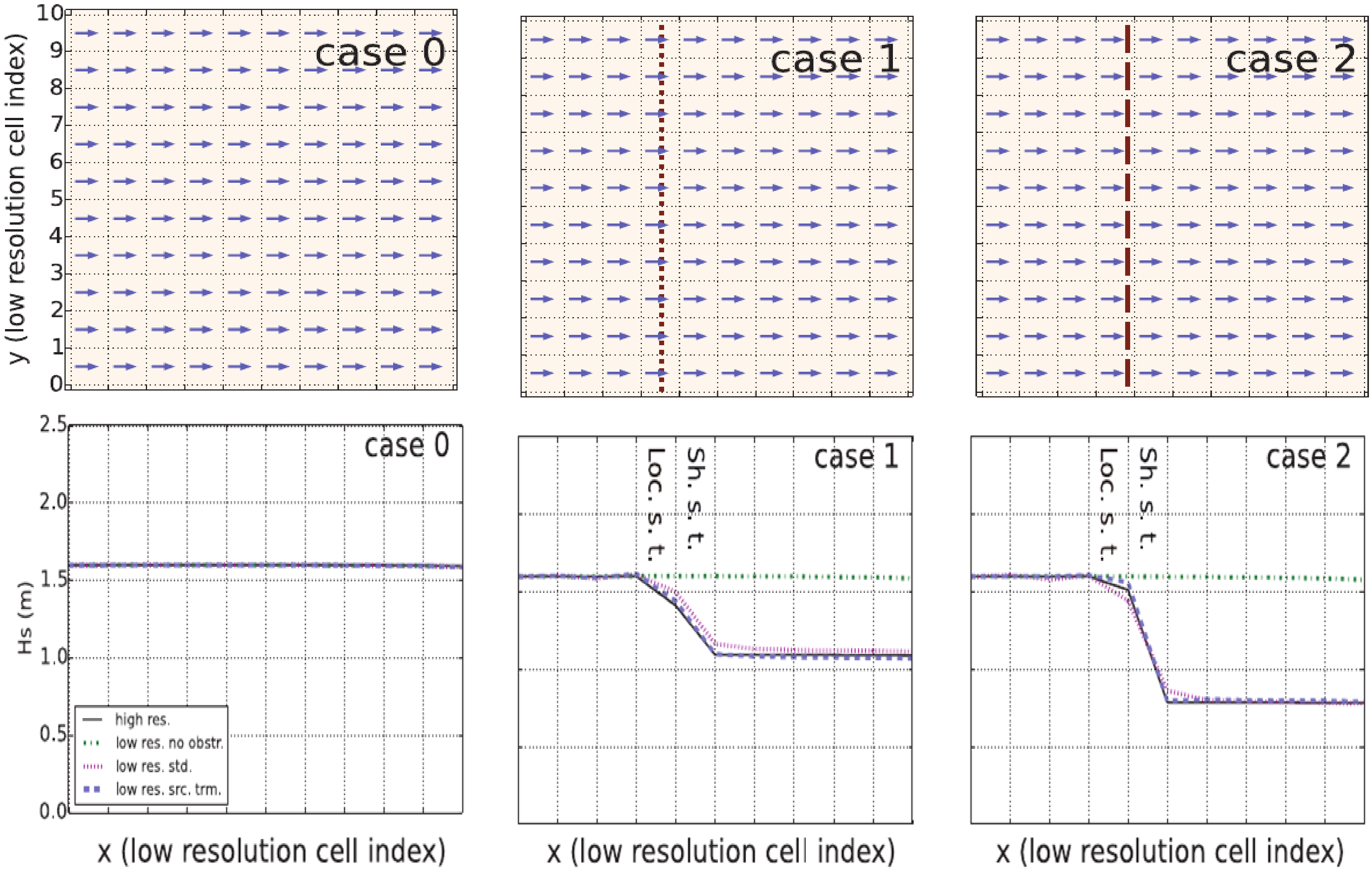
$$\left.\frac{\partial F}{\partial t}\right|_{SE} = -D\left(\frac{\beta_u}{\alpha_u} - 1\right)F$$

$$D = \psi(\upsilon, \Delta t)\sqrt{\left(\frac{c_{gx}}{\Delta x}\right)^2 + \left(\frac{c_{gy}}{\Delta y}\right)^2}$$

Total block: α --> 1

$$\left.\frac{\partial F}{\partial t}\right|_{LD} = \left.\frac{\partial F}{\partial t}\right|_{SE} = -D\gamma F, \gamma >> 1$$

Mentaschi et al. 2015 - Parameterization of unresolved obstacles in wave modelling



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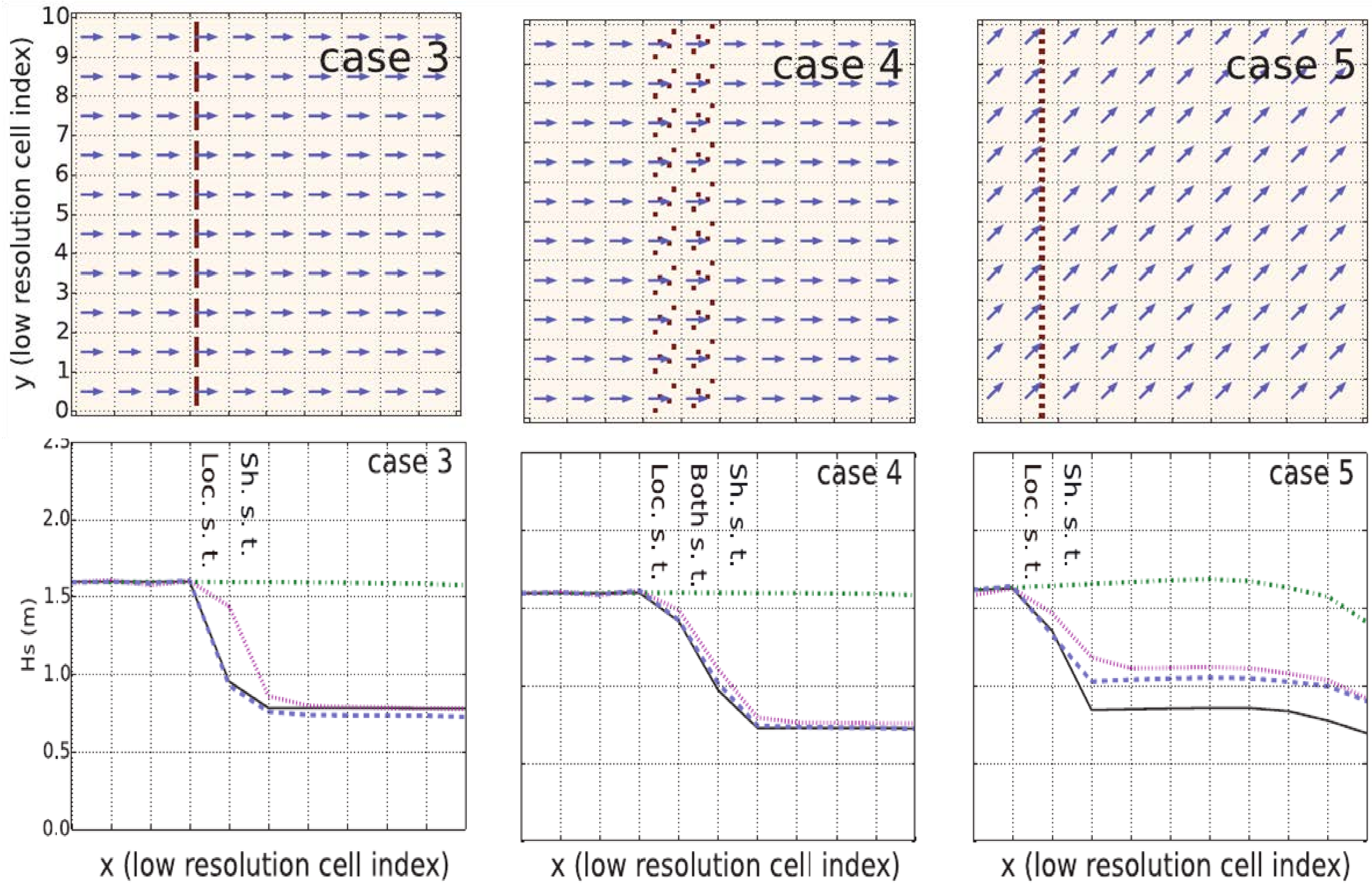

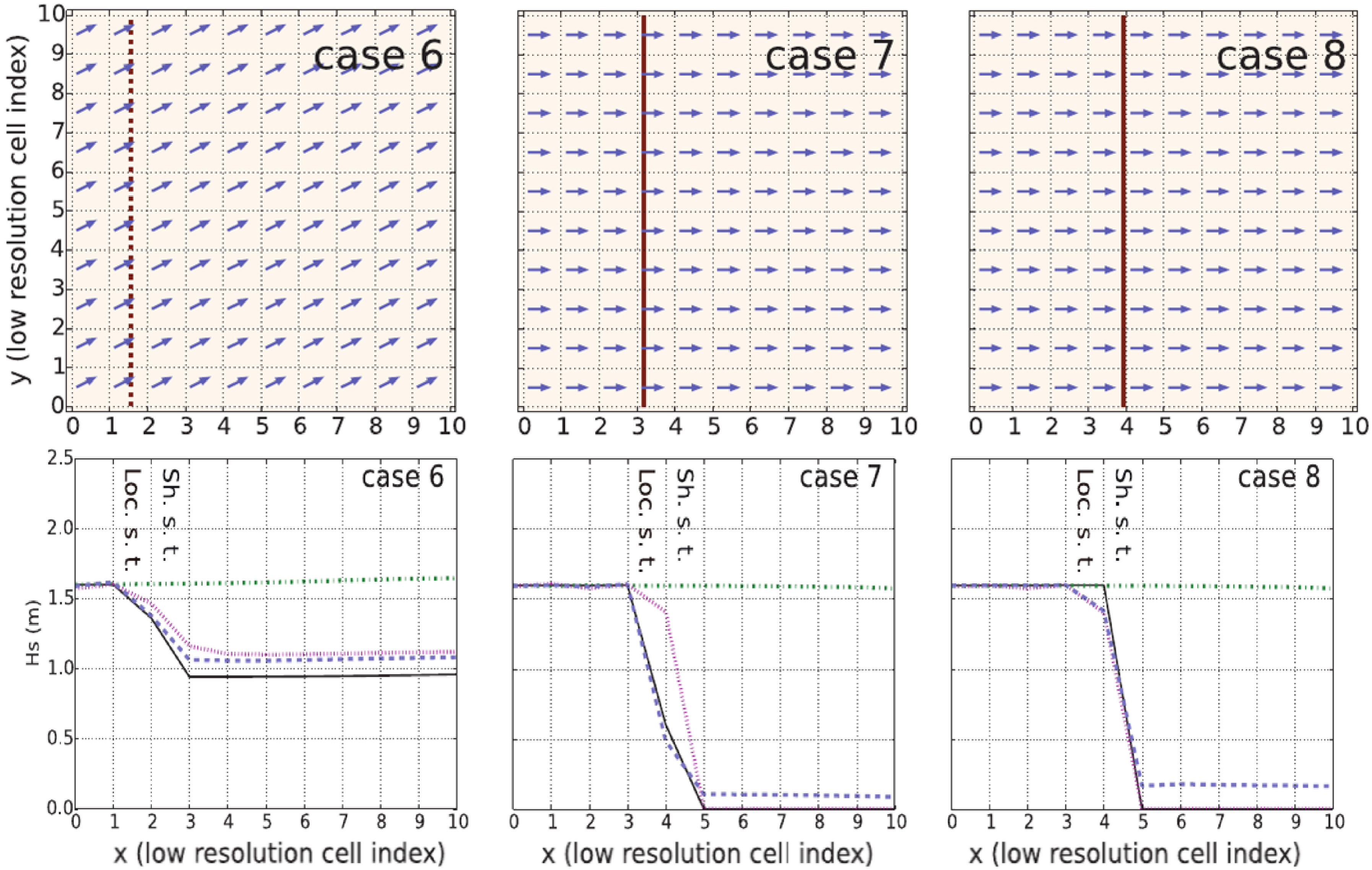
case 6
case 7
case 8
y (low resolution cell index)
Loc. s. t.
Sh. s. t.
Hs (m)
x (low resolution cell index)

WIP: what's new

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Implementation of a library (alphaBetaLab) able to compute α and β on whatever polygon. This is achieved computing for each spectral component the cross section of the obstacles contained inside the polygon.

Input:

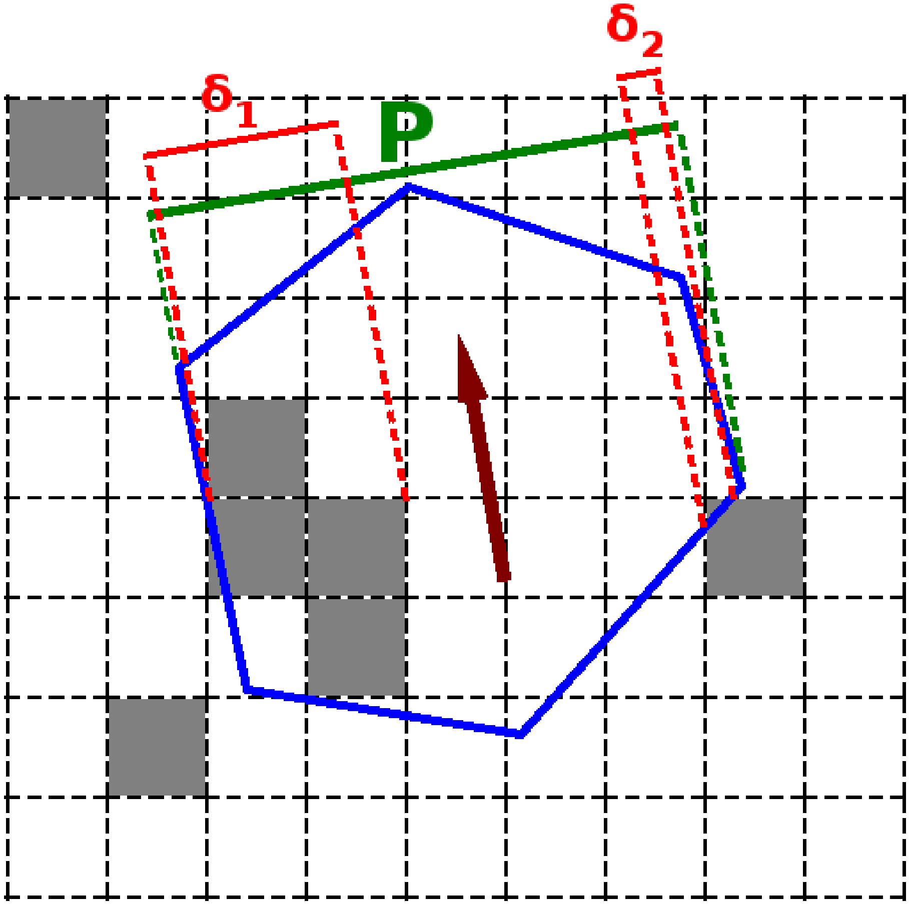
- a regular high resolution grid of transparency coefficients α;
- a polygon corresponding to a low resolution cell of whatever type.

Output:

α and **β** for the low resolution cell/polygon

In the example:

$$\alpha = 1 - \frac{(\delta_1 + \delta_2)}{P}$$



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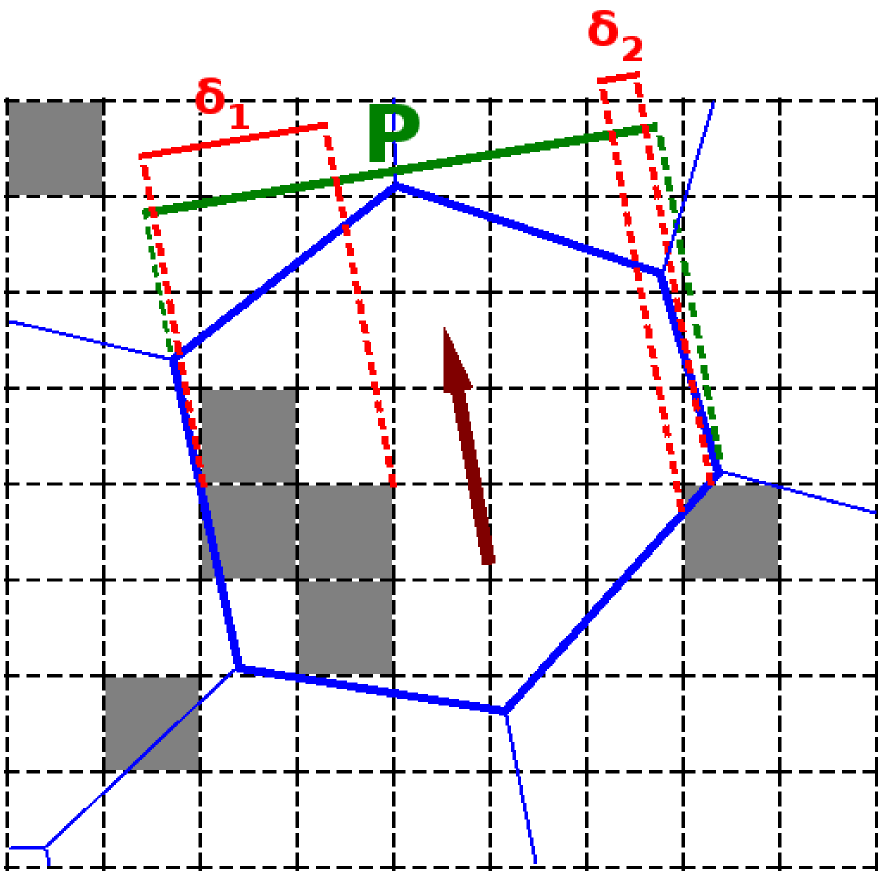
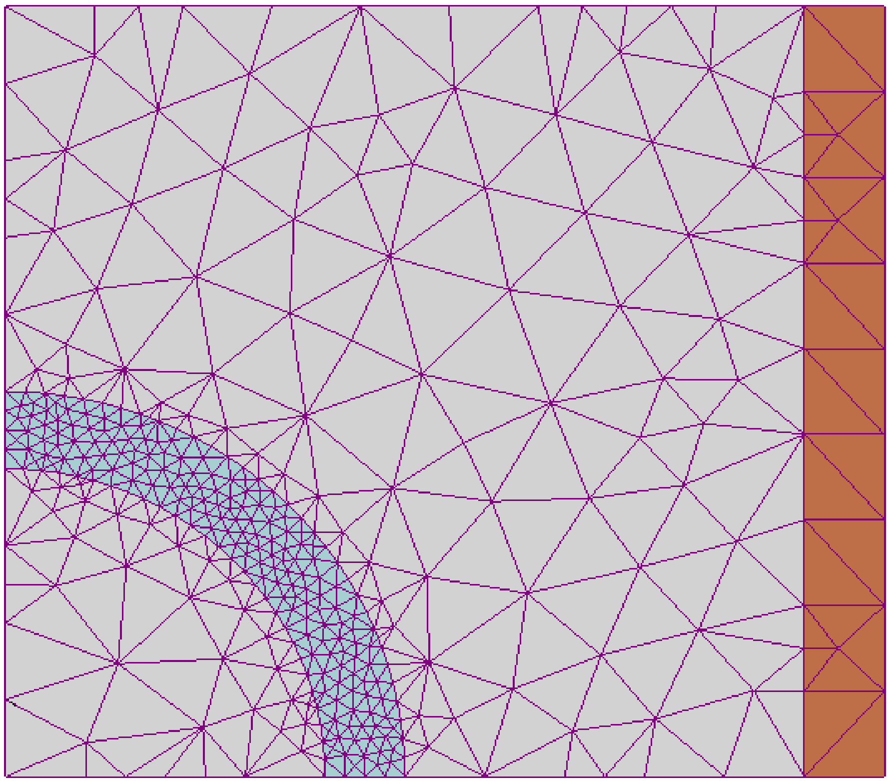
This is a step towards the implementation on unstructured grids





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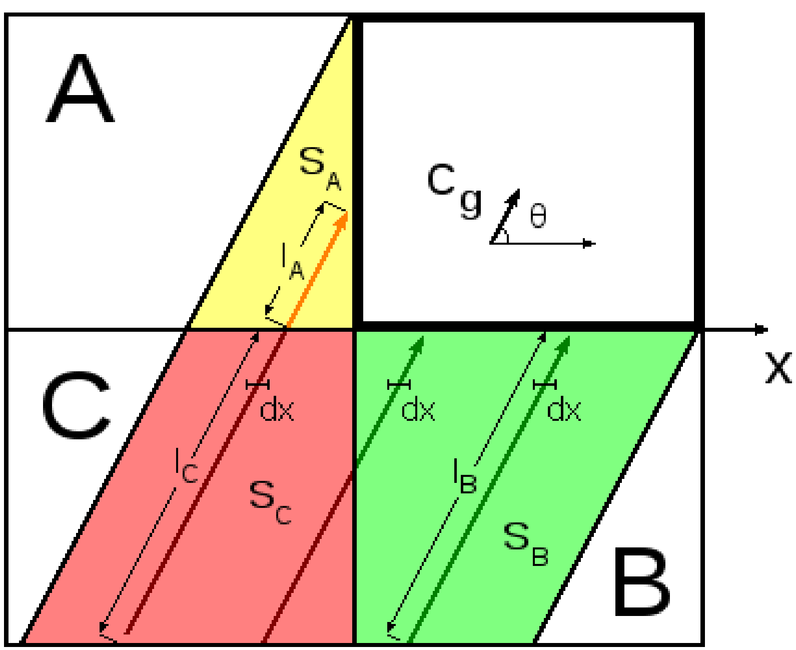
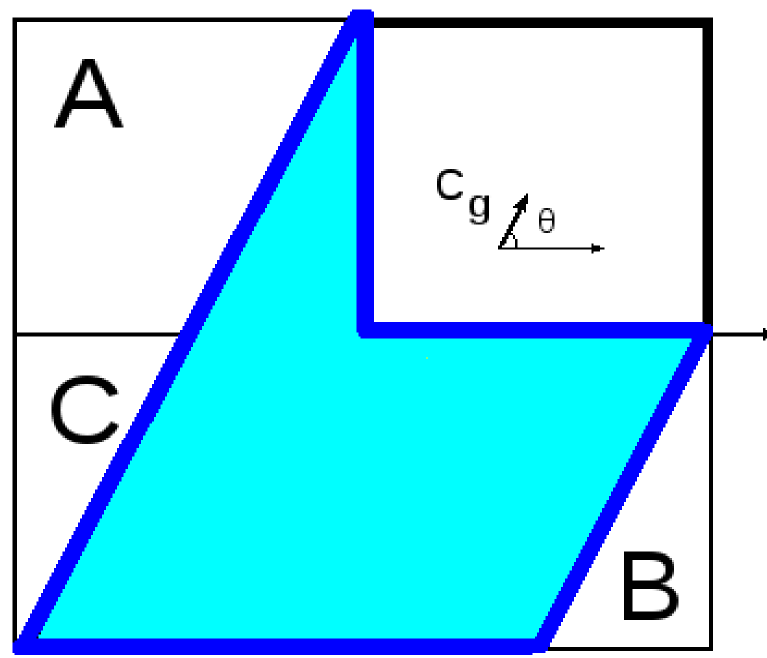
Improvement in the 2-d generalization of the shadow effects

Old approach: the shadow α and β are computed inside WWIII as a weighed average of the α and β of the upstream cells.



New approach: the shadow α and β are computed by alphaBetaLab on the upstream polygon. The model loads 2 different sets of α and β.



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Improvement in the 2-d generalization:

Simplification of the code on the side of WWIII

- In the old approach the search of the upstream cells would not be completely independent from the used propagation scheme.

- In the new approach the code for the source terms is exactly the same for all of the propagation schemes.

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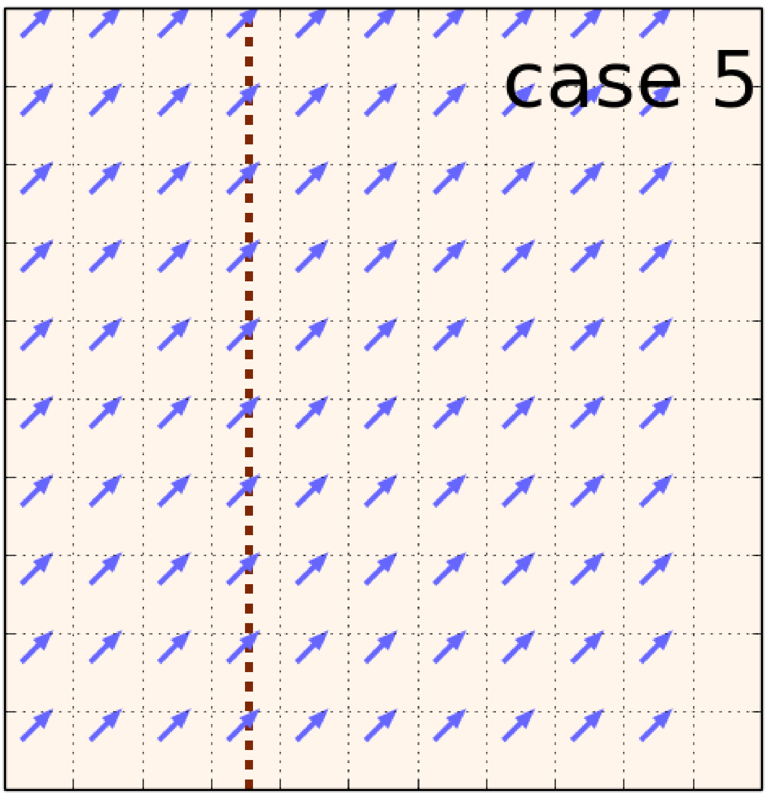
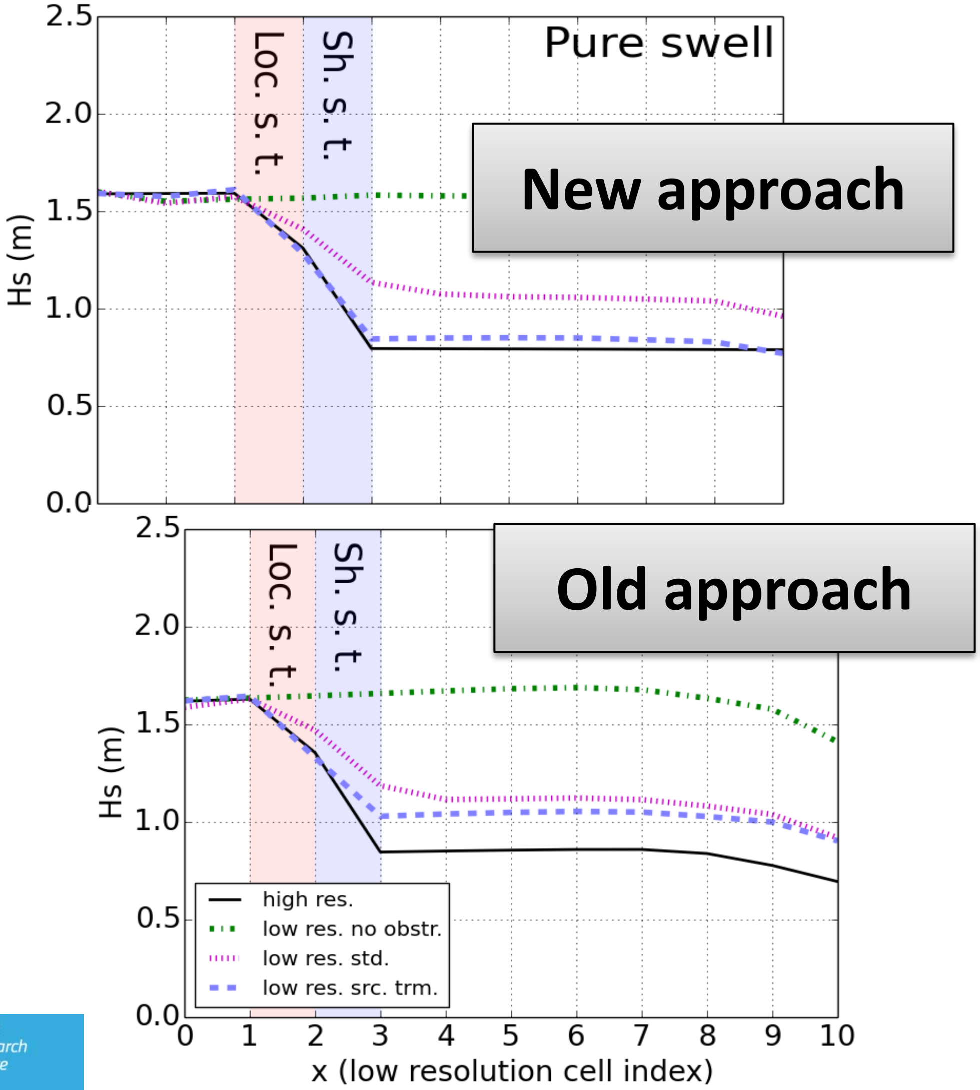
Improvement in the 2-d generalization of the shadow effects





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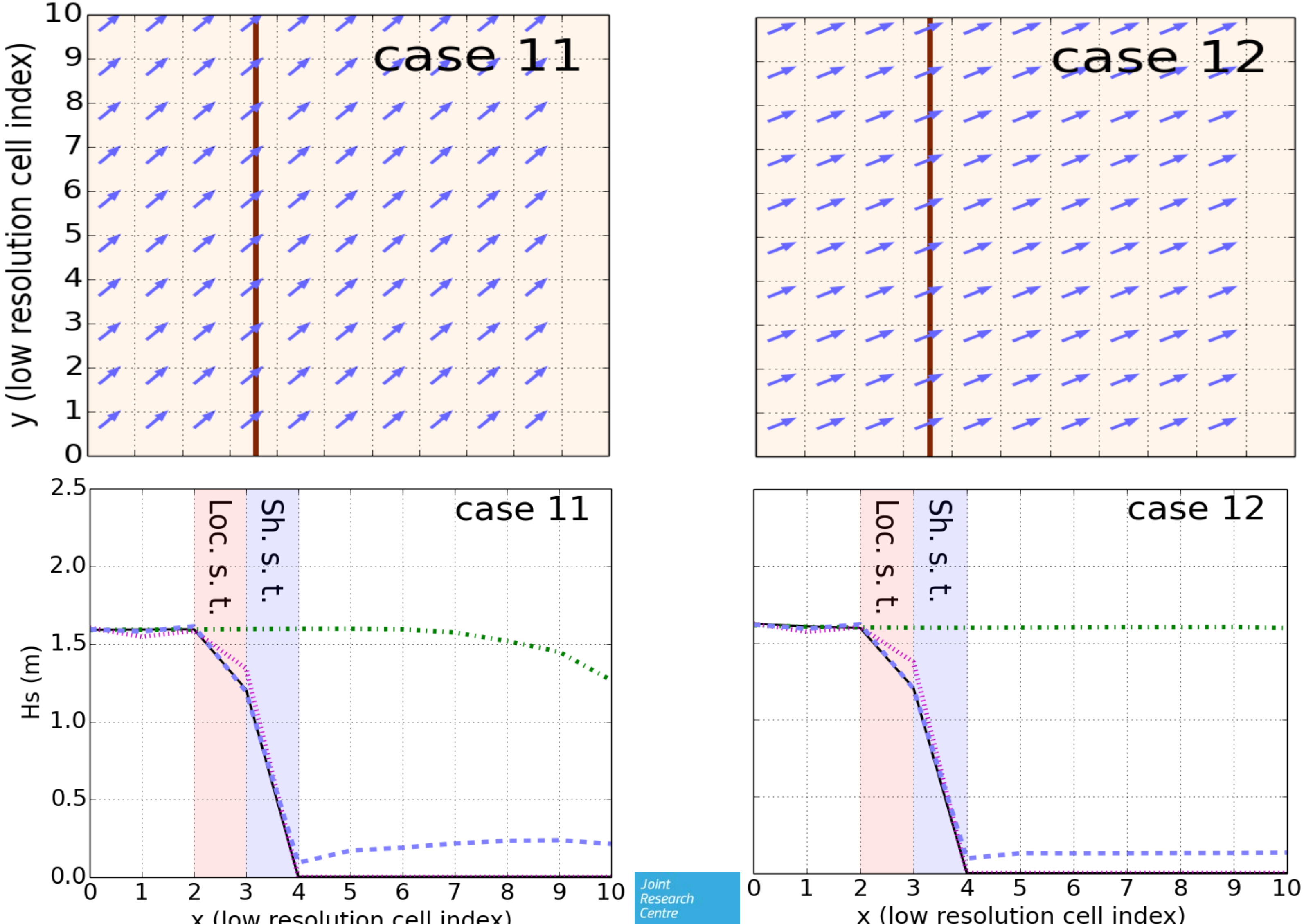
Total block 2-d



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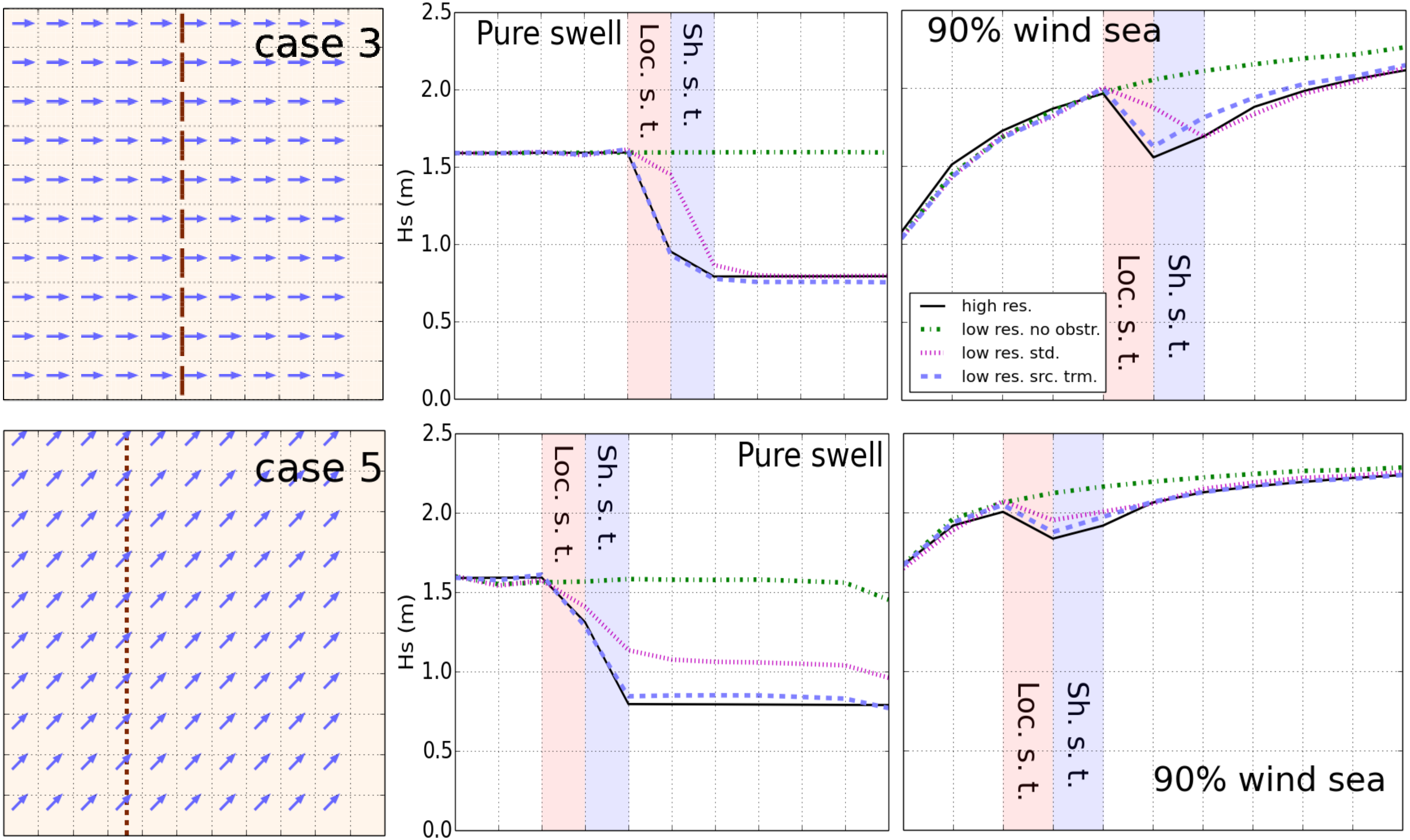
WIP: what's new

Wind wave growth: results look acceptable without any correction



WIP: what's new

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Estimation of the splitting error associated to the wave growth

$$\Delta F_{grw} = S_{grw}(F_{ex} + \Delta F_{LS})\Delta t$$

We are overestimating the wave growth!

$$E(\Delta F_{grw}) \approx S_{LS} S_{grw} \Delta t^2 F$$

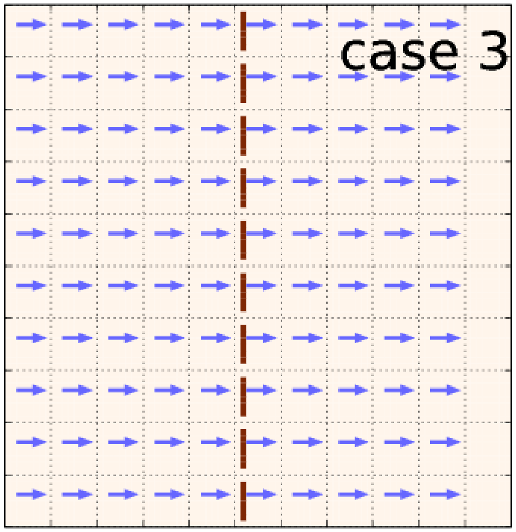
The correction factor is the same for the local and the shadow source terms

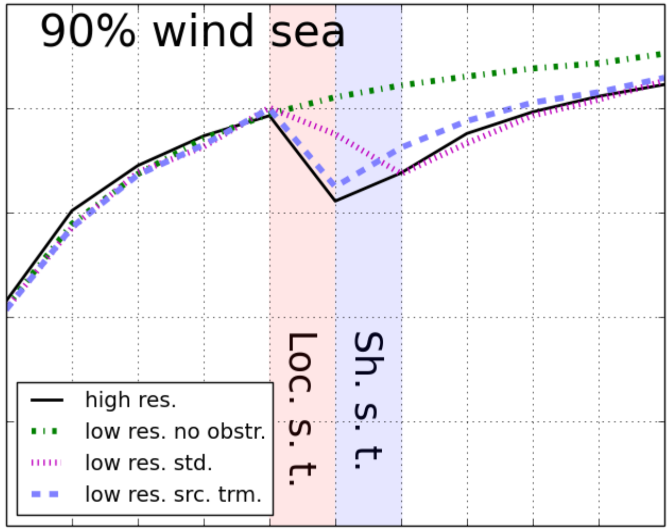
$$\psi(\upsilon, \Delta t) \approx 1 + S_{grw}\Delta t \approx 1 + \frac{\eta}{\upsilon^2}\Delta t$$

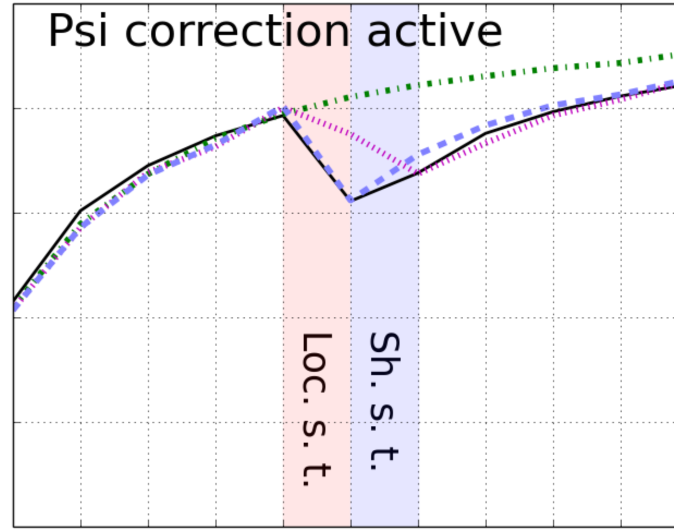
WIP: what's new

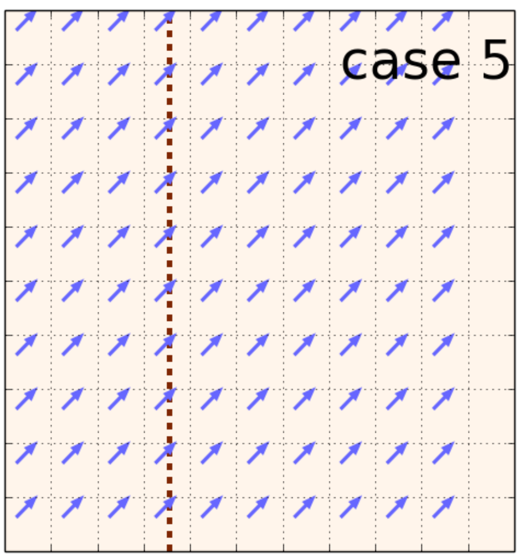
Application of the ψ correction

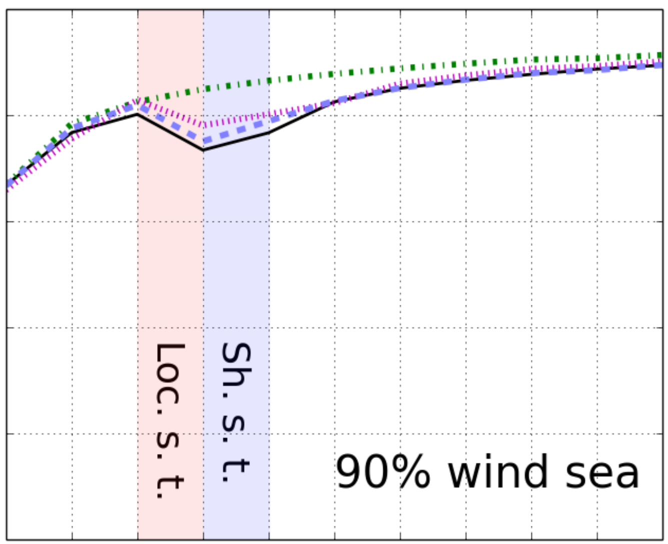
$\eta = 1.5 \cdot 10^{-4}\ s^{-1}$

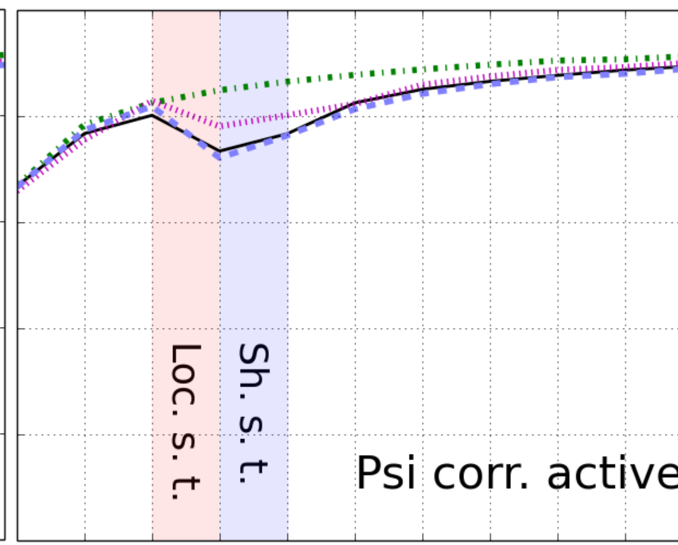












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Open points

- Optimization of the performances of alphaBetaLab
- For finite elements prop. schemes: deduction of the polygons from the msh files
- Further tests in presence of strong wind sea
- Who generates the input for alphaBetaLab? … gridgen? high resolution stationary models?
- Tests on real cases
- Unresolved rotations

…..

Perspectives

Not only unresolved obstacles

- With this technique you can parameterize whatever dissipating term varying on length scales smaller and time scales larger than those of the model, for example the effects of the ice floes.
- In this respect it could be interesting to couple wave models with models to estimate time-varying high resolution α coefficients through alphaBetaLab.

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Thank you!

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