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The Unresolved Obstacles Source Term, application cases on regular and triangular meshes

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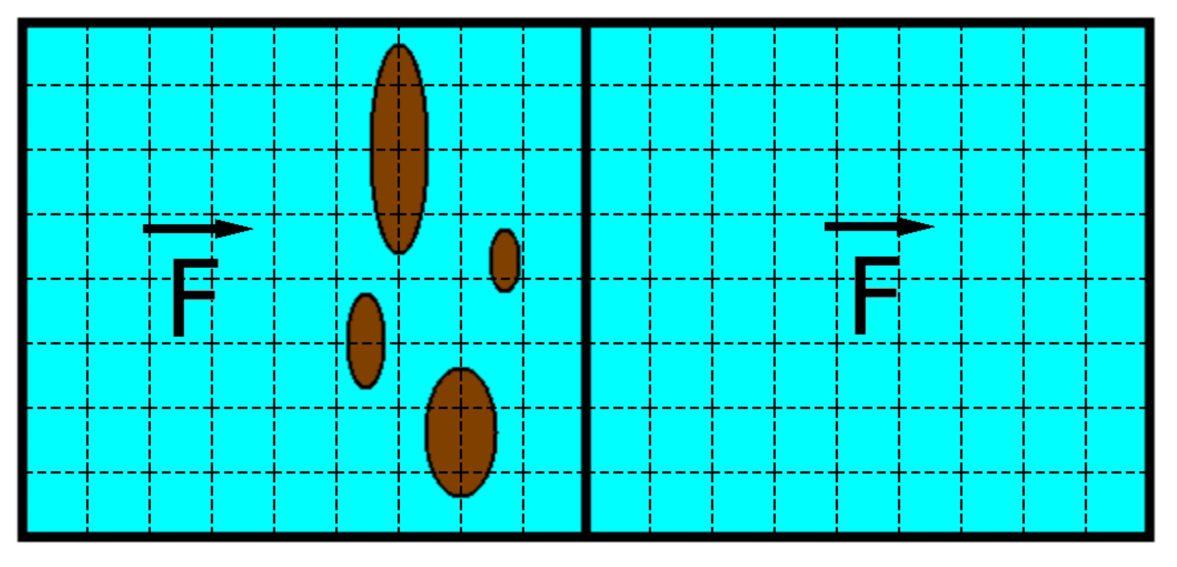
Unresolved Obstacles Source Term (UOST)

Approach to parameterize the effect of small islands based on source terms

LD-SE scheme: 2 source terms:
- Local Dissipation
- Shadow effect



For regular grids UOST comes as an alternative to the approach implmemented in the numerical scheme «GRIDGEN»

Advantages:
- it improves the model skill by considering obstacles layout and direction
- it can be applied to any type of mesh

PART OF RELEASE 6.07 OF WW3 (UOST SWITCH)

2 types of transparency coefficient

- For local and shadow dissipation
- For each spectral component

- **α**: total transparency

- **β**: obstacles layout-dependent transparency

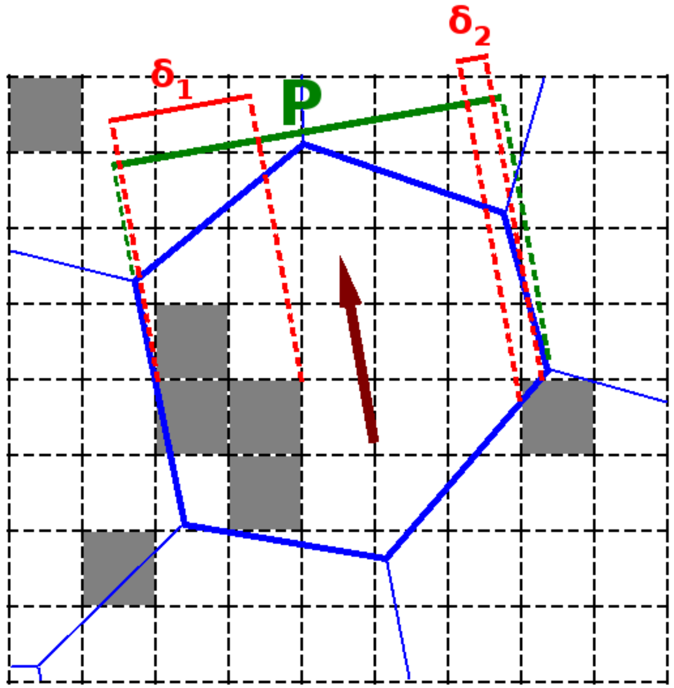
ELSEVIER

SoftwareX

Volume 9, January–June 2019, Pages 1-6

Original software publication

alphaBetaLab: Automatic estimation of subscale transparencies for the Unresolved Obstacles Source Term in ocean wave modelling



- Computes α and β for meshes from real bathymetries
- Python3 library (but no need to be a python programmer to use it)
- Supports regular and triangular meshes
- The computation is fully parallelized. Fast enough.
- Documentation:
    - Code available on github
    - Wiki page
    - Installation guide
    - Examples
    - Publication describing the architecture

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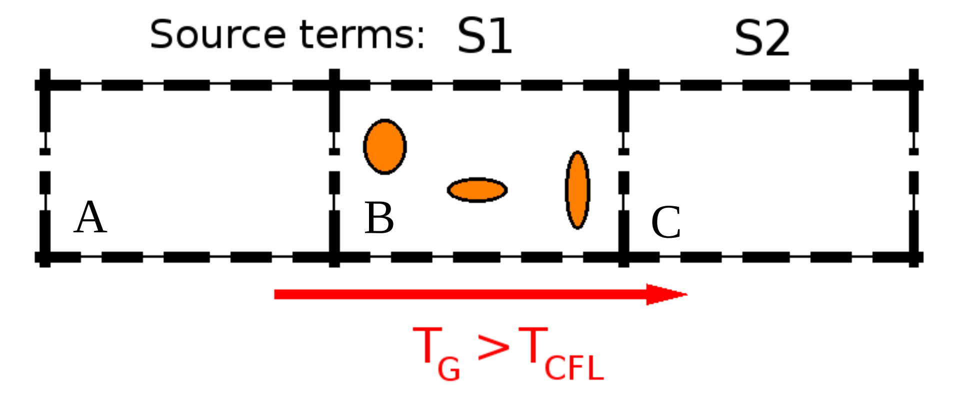
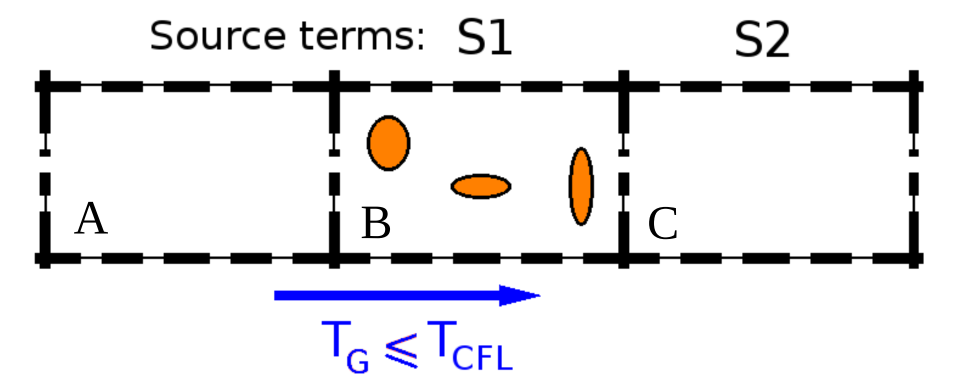
Time step settings:

for UOST to work properly at a given cell/spectral component …

- **the global time step (T_G) should be ≤ the critical CFL time step T_{CFL}**
- **$T_G > T_{CFL}$: the energy travels through more than one cell before the source term is applied. LEAKAGE OF ENERGY.**

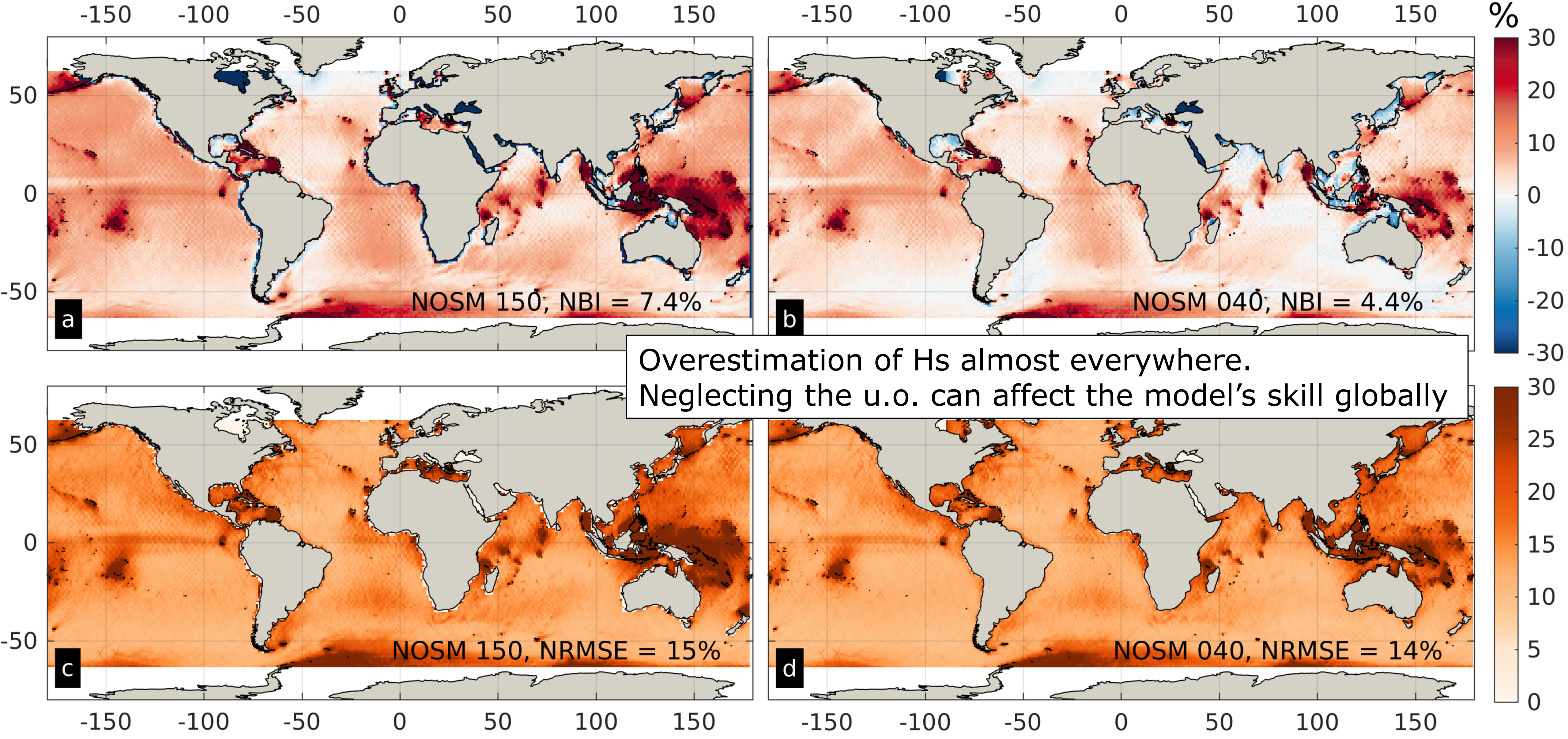


- **$T_G \leq T_{CFL}$: the energy travels through less than one cell before the source term is applied.**



Importance of representing subscale obstacles

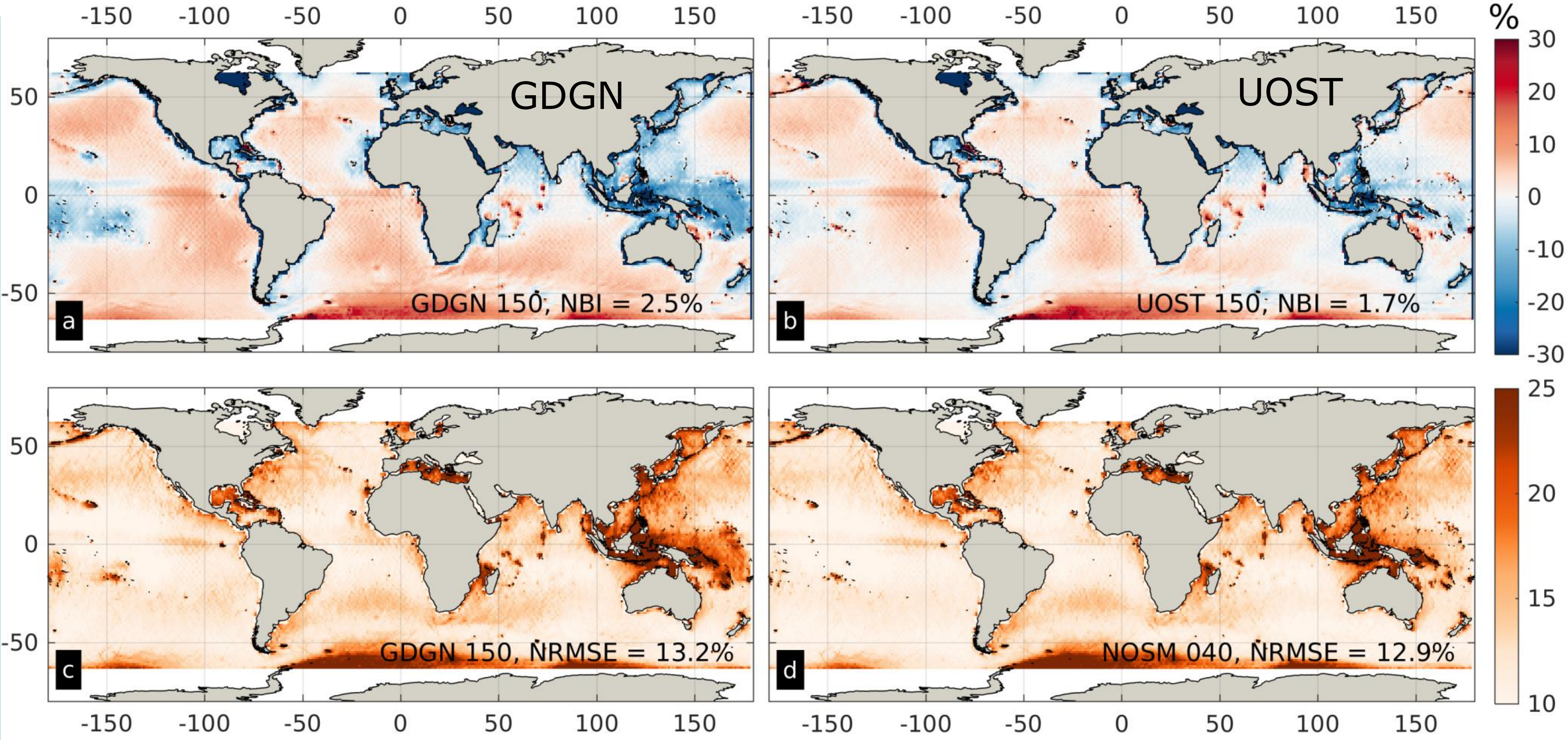
(10 years runs at resolutions 1.5° and 0.4°, forced by CFSR, validation with sat. altimeters)



Overestimation of Hs almost everywhere.
Neglecting the u.o. can affect the model’s skill globally

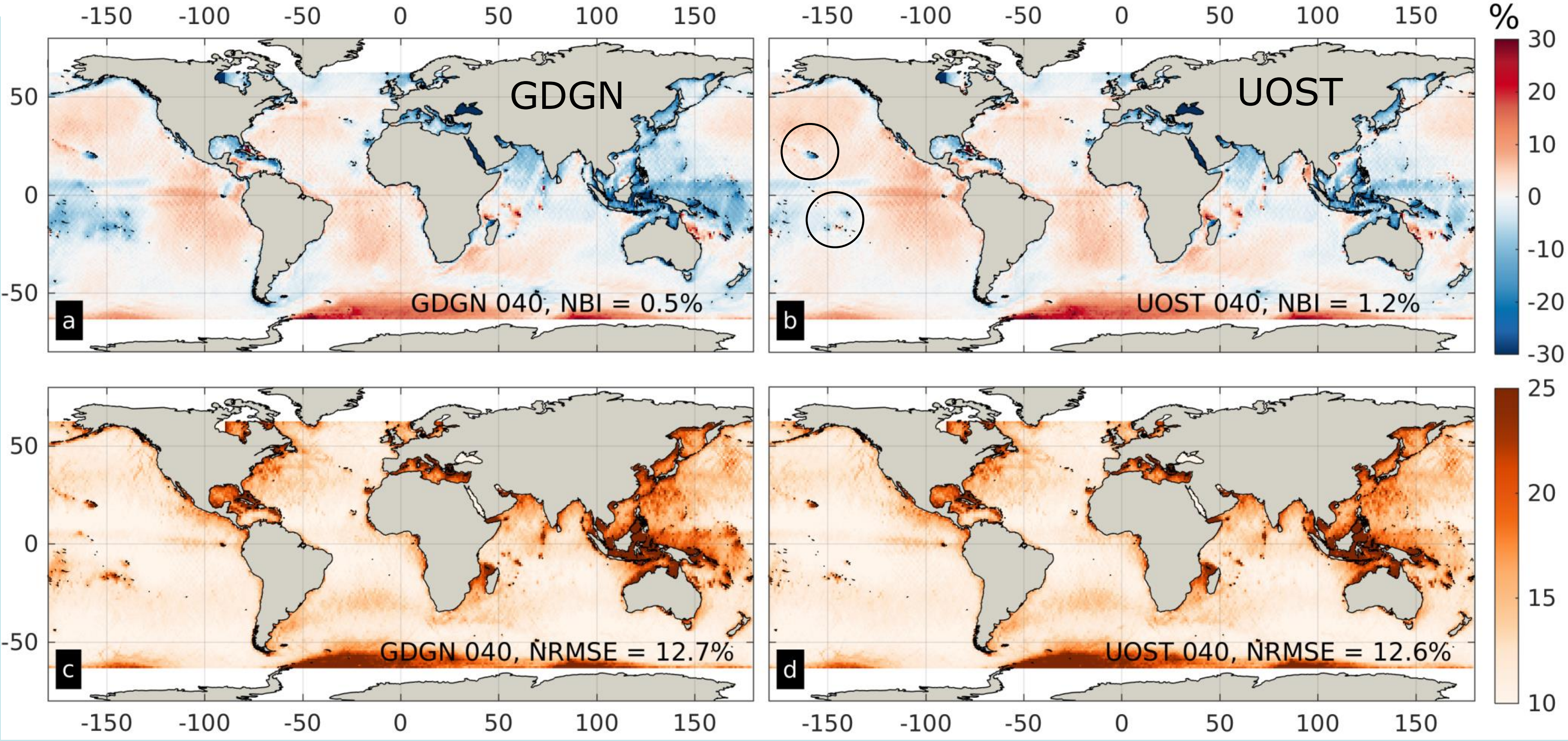
The effects of subscale modelling at 1.5° res.

Model's skill improves a lot if any u.o. parameterization is adopted



- Improves the skill more than increasing the resolution up to 0.4°.
- In many areas UOST is doing better.

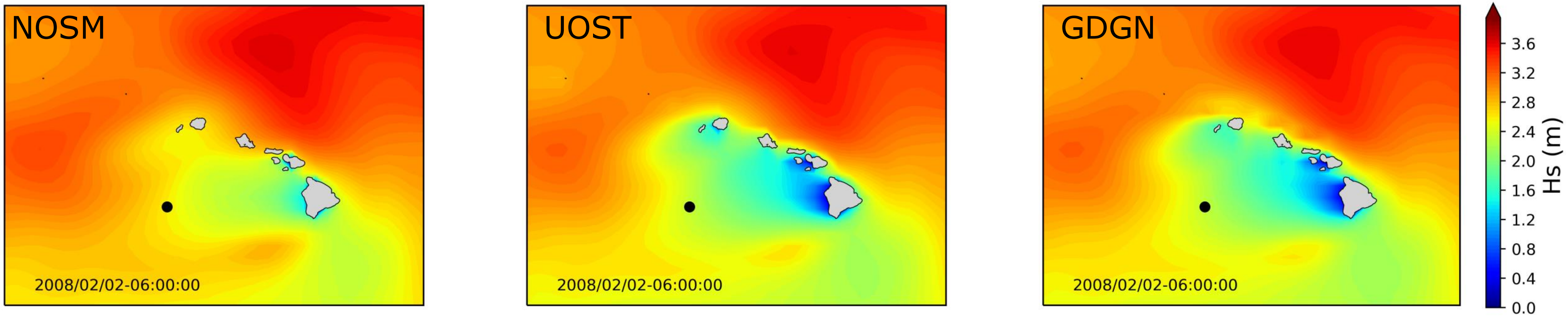
The effects of subscale modelling at 0.4° res.

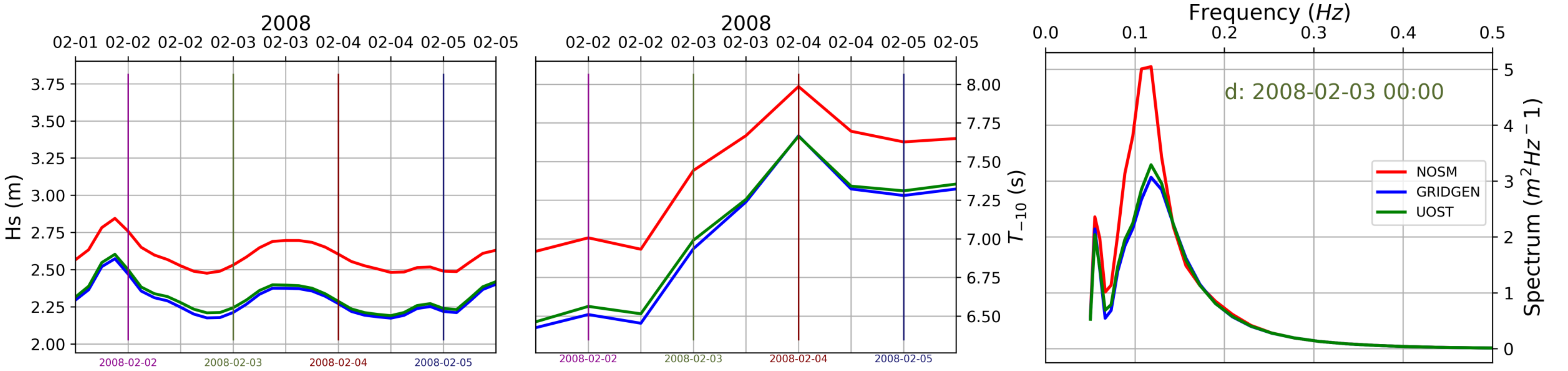


- Still, in areas with small islands UOST is doing better
- Apparently, in some areas GDGN overestimates the effect of the unresolved island
- Hypothesis:the differences btw GDGN and UOST are mainly in the diagonal swell

Unresolved obstalces in a longitudinal swell (0.4°)

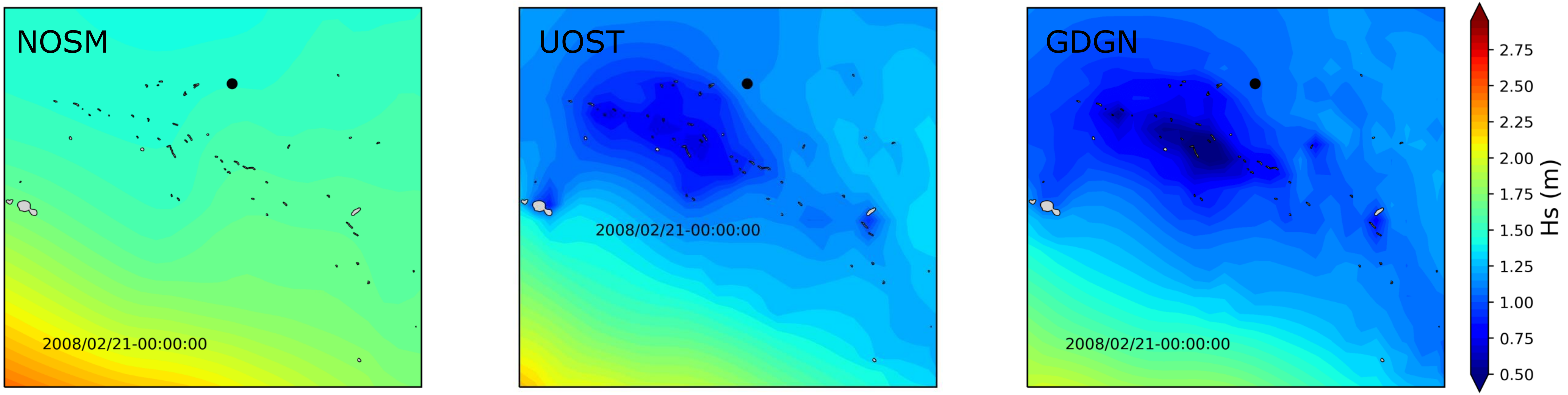
UOST and GDGN are almost identical

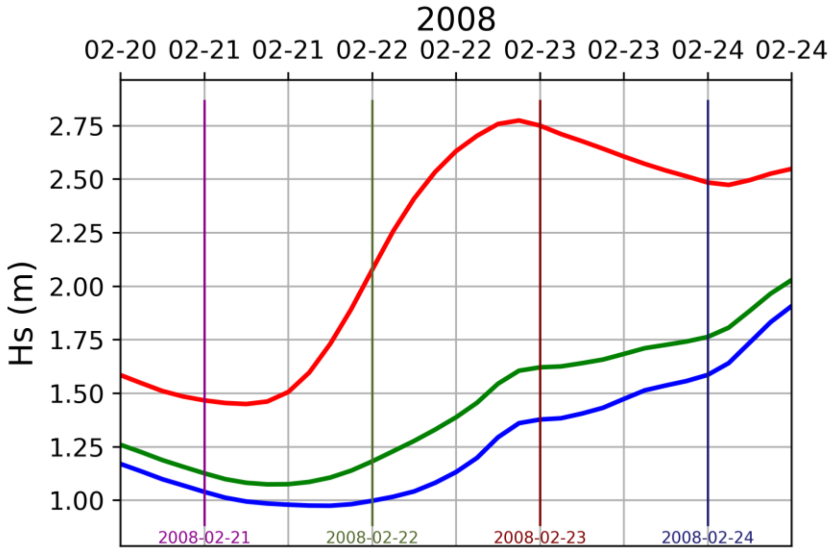


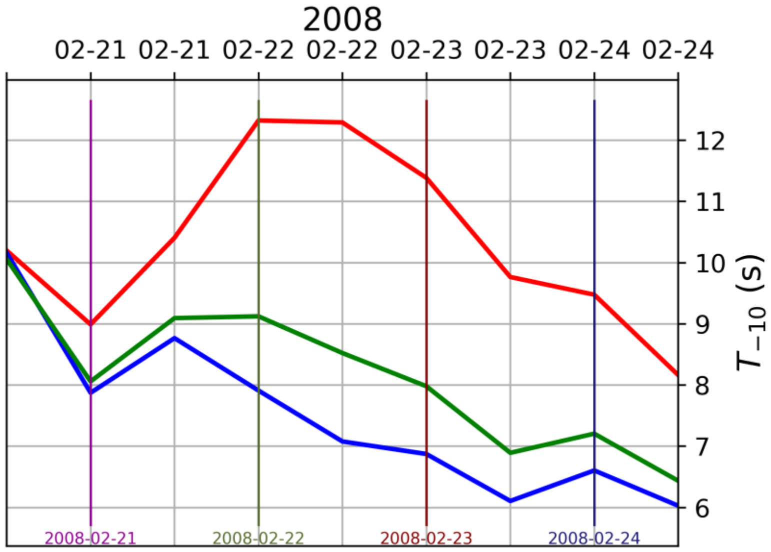


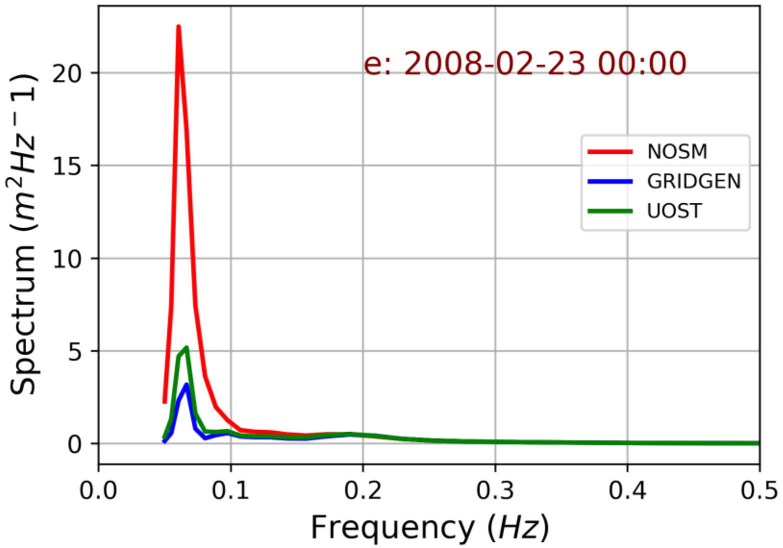
Unresolved obstalces in a diagonal swell (0.4°)

Significant differences between UOST and GDGN





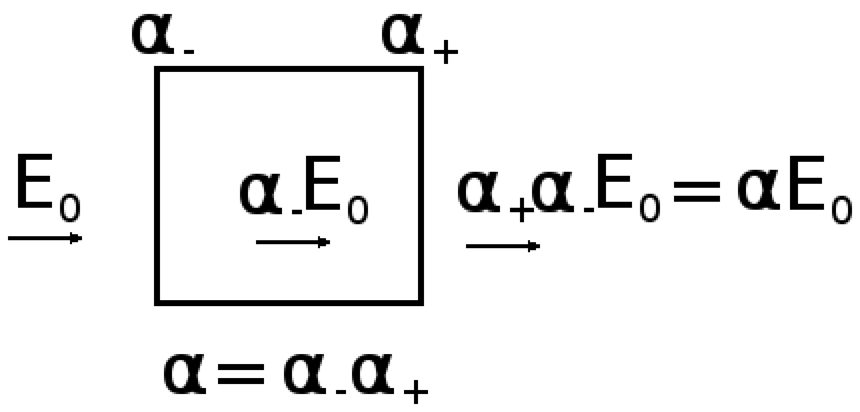




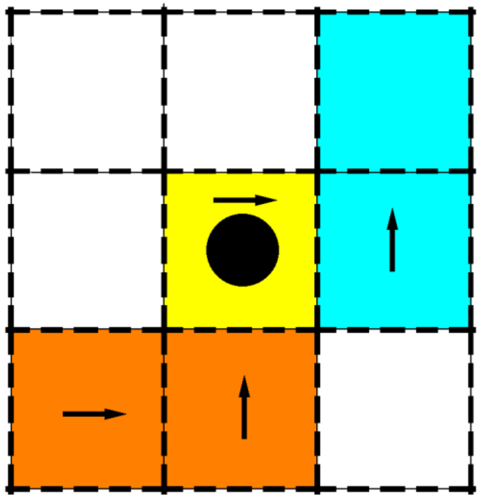
Possible explanation of GDGN overdissipation in diagonal swell

(a monochromatic thought experiment with a circular island)

... how does it work?



Behavior with diagonal swell
(circular island with α=0.5)

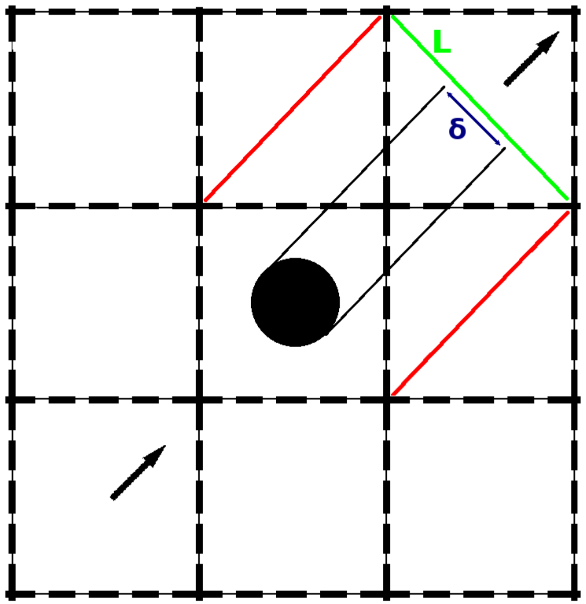


$\alpha=0.5=\alpha_+\alpha_-$
$\alpha_-=0.75$
$\alpha_+=0.667$

- E_0
- $\alpha_- E_0=0.75\,E_0$
- $\alpha E_0=0.5\,E_0$

The final energy is $0.5E_0$

... but the diagonal cross-section is 0.35 ...



Cross section:

$Kr = \frac{\delta}{L} = 0.35$

... the final energy should be $0.65E_0$

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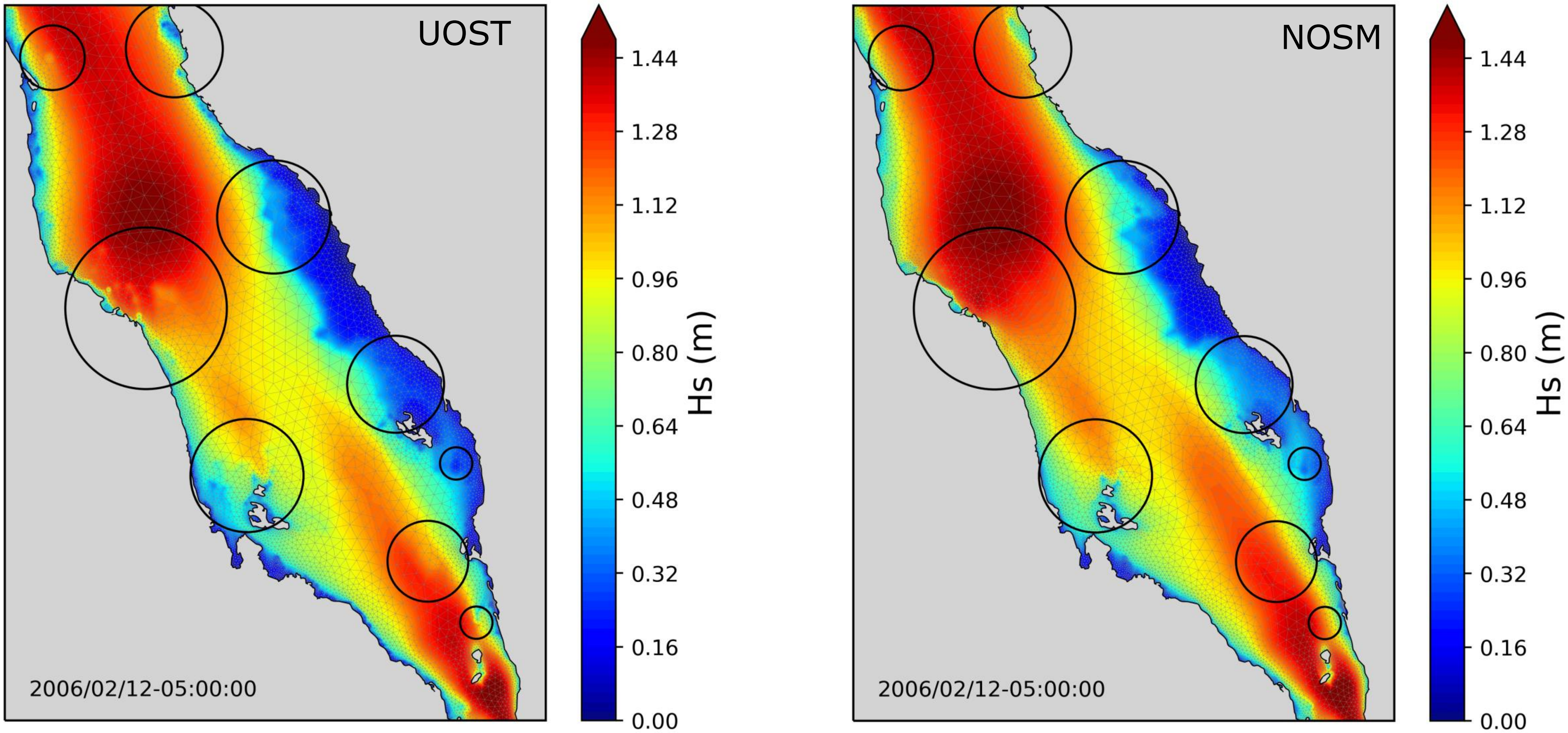
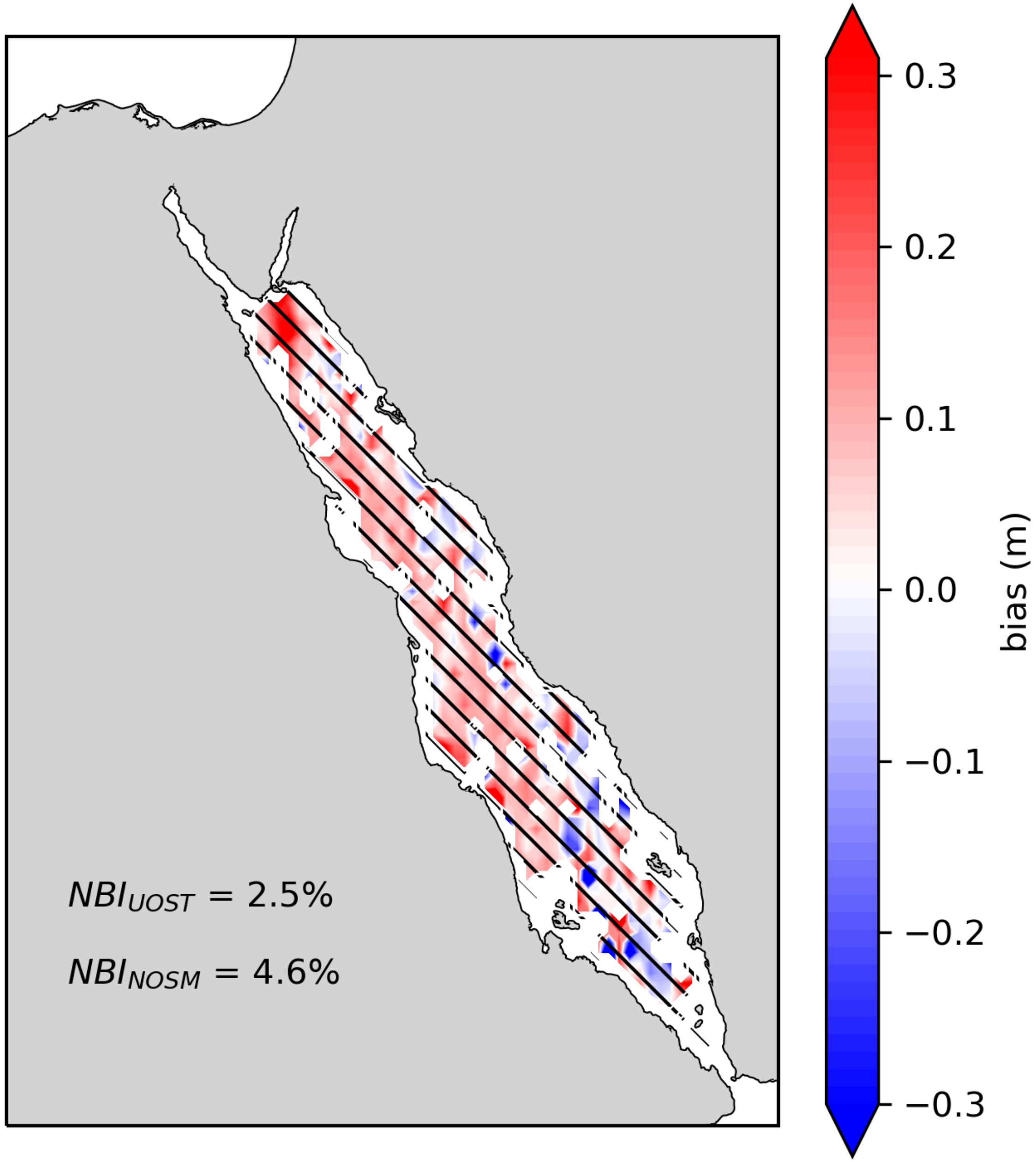
UOST and triangular meshes

- UOST can help the modeller to better concentrate on the areas of interest, and not to increase the resolution at any small island.
- Case study: triangular mesh with 15km res. offshore and 2km nearshore. Forcing from downscaled CFSR.



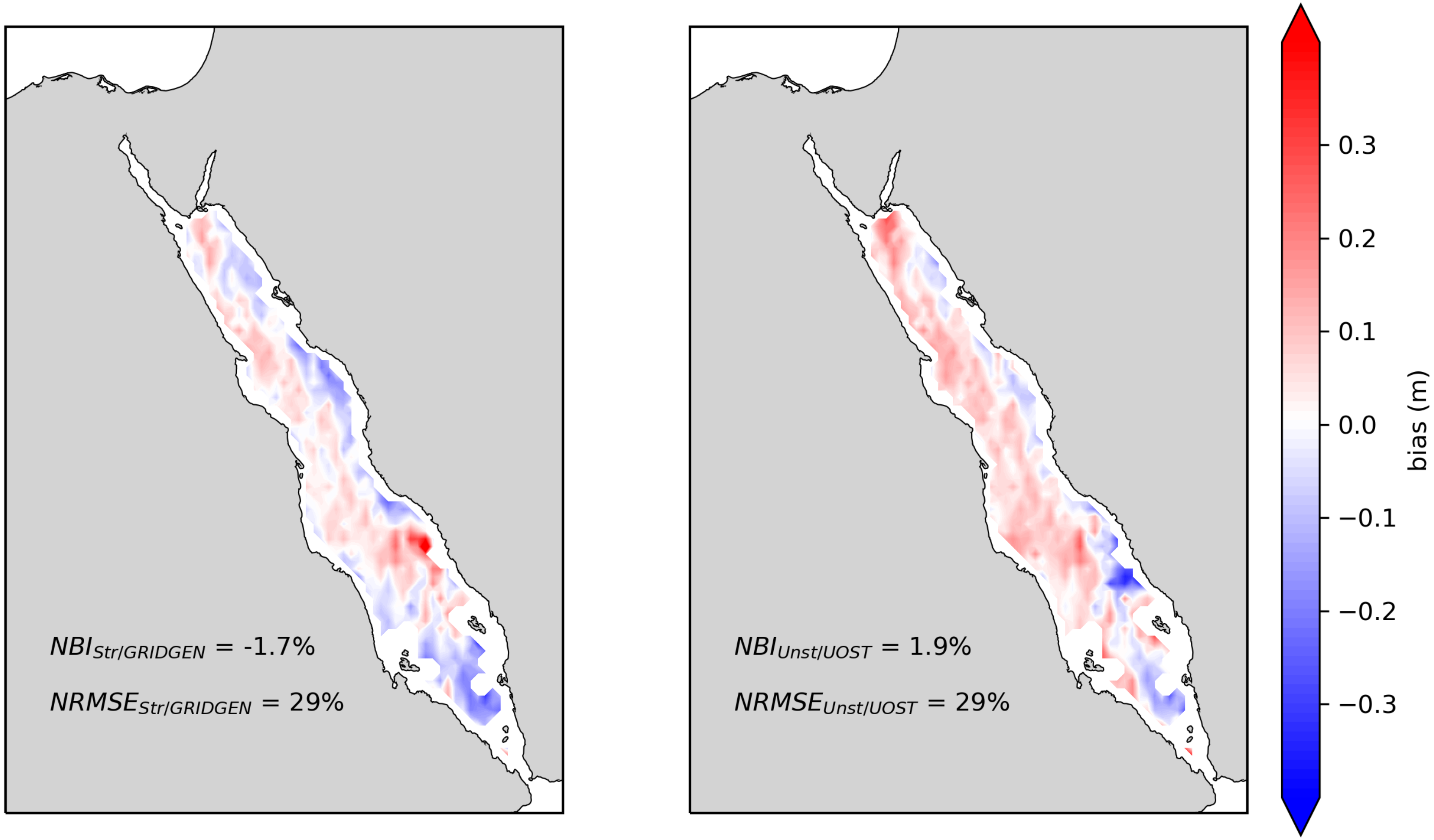


Comparison between UOST and NOSM:

- validation offshore versus satellite altimeters (10 years).

- UOST significantly reduces the model bias (shaded areas).

Comparison btw triangular (UOST) and regular (GDGN)



- unstructured setup with 15km res. offshore and 2km res. nearshore.
- regular setup with 3-km res.
- validation offshore versus satellite altimeters (30 years).
- comparable model skill, but **the triangular mesh is computationally cheaper,** having at the same time **a higher coastal resolution**

Final remarks

- The parameterizing u.o. plays an important role in the skills of a model: a 1.5° res. model with a parameterization of u.o. performs better than a 0.4° res. model without.

- In regular grids UOST can improve the model skill by better representing the geometry and the layout of the obstacles, especially in presence of diagonal swell.

- In triangular meshes UOST removes the need of increasing the resolution in proximity of any small feature, potentially leading to
  - the simplification in the development process of large scale meshes
  - a significant decrease of the computational demand of accurate large scale meshes.

- UOST is part of WW3 6.07 (UOST switch)

References

Mentaschi, L., Pérez, J., Besio, G., Mendez, F. J., & Menendez, M. (2015). Parameterization of unresolved obstacles in wave modelling: A source term approach. Ocean Modelling, 96, 93-102.

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Any questions?

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UOST equations

Local Dissipation s.t. :

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

Shadow Effect s.t. :

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

Total block: α --> 0

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

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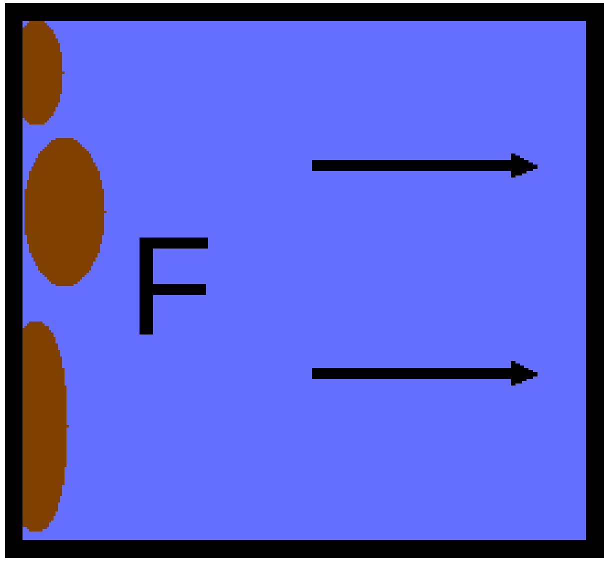
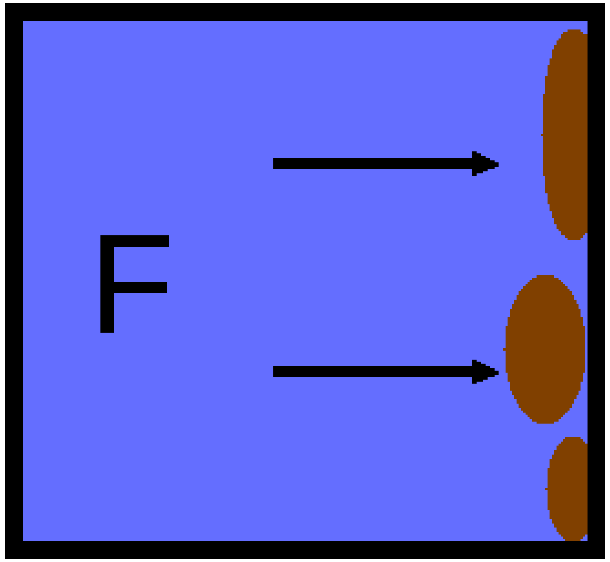
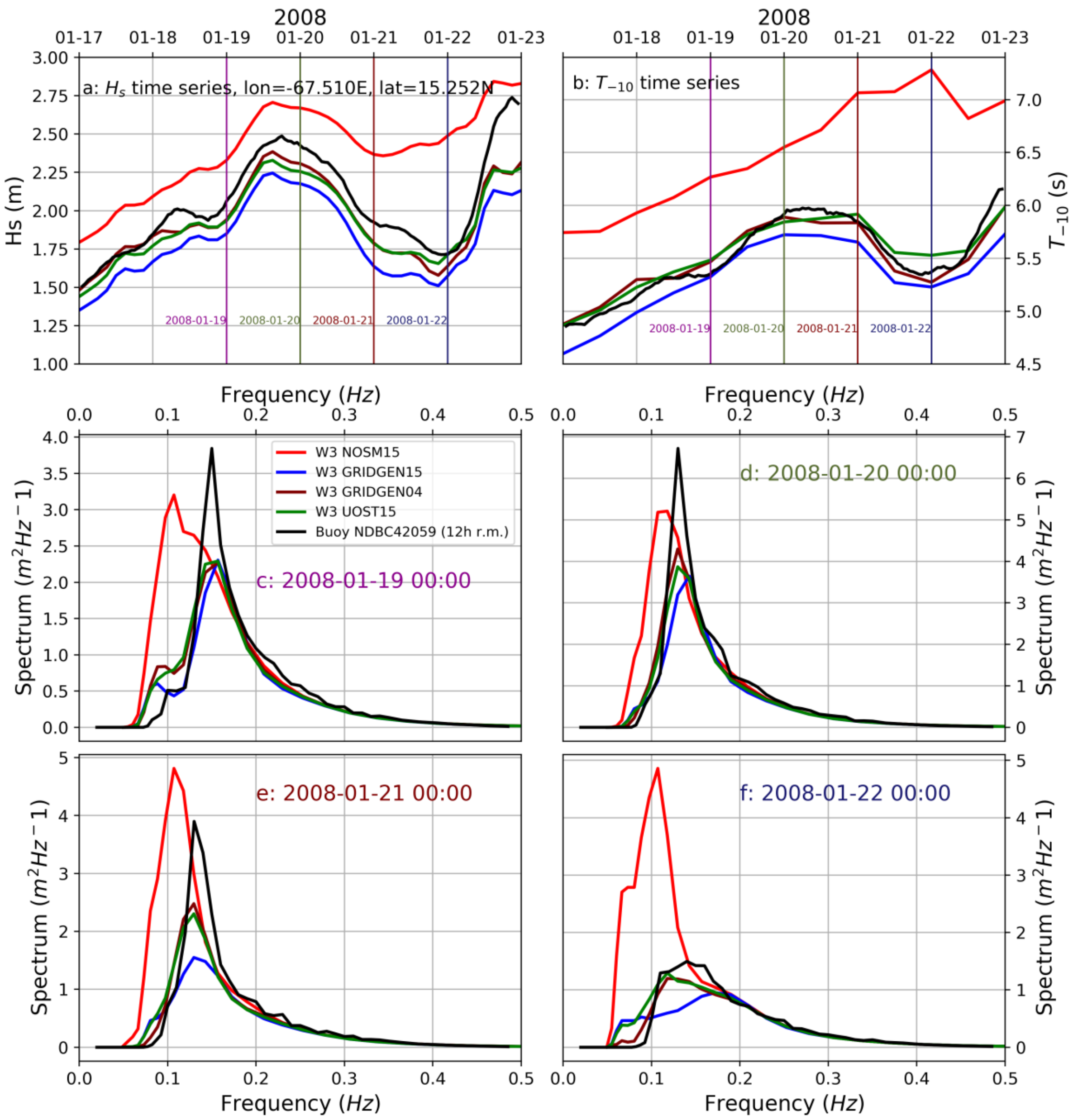
Meaning of β

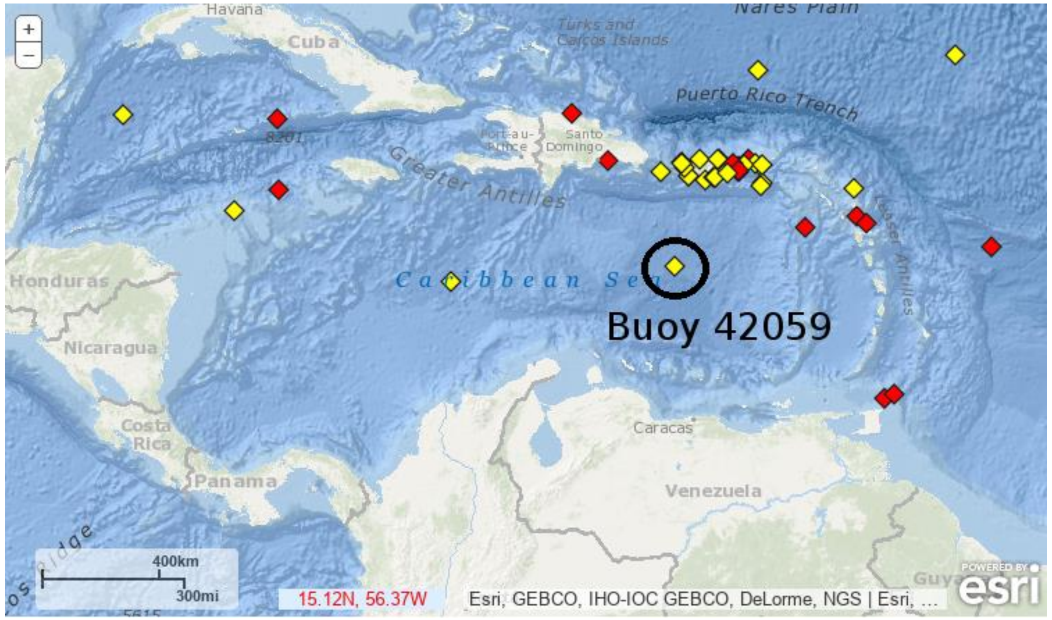
β ≈ α: all the unresolved obstacles are close to the upstream side.



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







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