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

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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 implemented 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

• \( \alpha \): total transparency

• \( \beta \): obstacles layout-dependent transparency
Computes $\alpha$ and $\beta$ 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
Time step settings:
for UOST to work properly at a given cell/spectral component …

- the global time step ($T_G$) should be $\leq$ 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 $1.5^\circ$ and $0.4^\circ$, forced by CFSR, validation with sat. altimeters)

Overestimation of $H_s$ 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 between GDGN and UOST are mainly in the diagonal swell.
Unresolved obstacles in a longitudinal swell (0.4°)

UOST and GDGN are almost identical
Unresolved obstacles 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?

$E_0 \rightarrow \alpha_- \alpha_+ \rightarrow \alpha_- \alpha_+ E_0 = \alpha E_0$

$\alpha = \alpha_- \alpha_+$

Behavior with diagonal swell (circular island with $\alpha=0.5$)

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

Cross section: $Kr = \frac{6}{L} = 0.35$

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

The final energy is $0.5E_0$
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).

$NBI_{UOST} = 2.5\%$

$NBI_{NOSM} = 4.6\%$
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)
Any questions?

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UOST equations

Local Dissipation s.t. : \[ \frac{\partial F}{\partial t} \bigg|_{LD} = -D \left( 1 - \frac{\beta}{\gamma} \right) F \]

Shadow Effect s.t. : \[ \frac{\partial F}{\partial t} \bigg|_{SE} = -D \left( \frac{\beta}{\alpha} - 1 \right) F \]

Total block: \( \alpha \rightarrow 0 \)

\[ \frac{\partial F}{\partial t} \bigg|_{LD} = \frac{\partial F}{\partial t} \bigg|_{SE} = -D \gamma F , \gamma >> 1 \]
Meaning of $\beta$

$\beta \approx \alpha$: all the unresolved obstacles are close to the upstream side.

$\beta \approx 1$: all the unresolved obstacles are close to the downstream side. Their effect on the local cell is small.