NEMO-Wave Coupling Working Group
Ongoing work

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MAIN OBJECTIVES OF THE WG

Understanding the relevance of Atmosphere-Wave-Ocean exchanges processes and their roles in driving the ocean circulation at both coastal and global scales, the NEMO consortium has decided to dedicate specific effort to address this issue, creating a Working Group with the specific goal to identify required actions and models developments.

There are many processes occurring at the interface between the Atmosphere and the Ocean. We focus our attention on the Wave-Atmosphere-Ocean coupling. In particular the working group will explore the way in which surface gravity waves can influence the ocean circulation.

NEMO Consortium Members of the WG	External Experts of the WG
Emanuela Clementi (INGV)	Paolo Oddo (CMRE)
Damiano Delrosso (INGV)	Oyvind Breivik (ECMWF)
Michela De Dominicis (INGV)	Jean Bidlot (ECMWF)
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Francois Bocquet (METOFFICE)	Fabrice Ardhuin (IFREMER)
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Geroge Nurser (NOC)	Alain Grant (Univ. Reading)
Lucy Bricheno (NOC)	Piero Lionello (Univ. Salento)
Judith Wolf (NOC)	Stefanie Rynders (Univ. Southamton)

ACTUAL WAVE IMPLEMENTATION IN NEMO

- Surface Drag (neutral from wave, turbulent added in NEMO);
- 3D stokes drift computation;
- External data: Neutral Surface Drag Coeff; Surface Stokes Drift; Mean Wave number

2014 WG ACTIVITIES

A 2-day **meeting** on atmo-wave-ocean current interactions has been carried out in May at ECMWF (Reading) with the participation of internal members and external experts.

- 1st day: scientific presentations and discussion
- 2nd day: technical implementation of wave effects in NEMO has been discussed

Meeting Minutes and a discussion document have been created and distributed

MAIN OUTCOMES

1st step development: implement a set of large scale wave effects

1) Technical issues have been identified with respect to a development branch created implementing the work done by ECMWF (Branch 2014/dev_r4642_WavesWG)
2) According to NEMO-ST the technical implementation must be carried out within the WG
3) A new branch has been created by INGV (branches/2014/dev_r4822_INGV_WAVE) starting implementing the actions that have been identified
4) Create a configuration to test wave related developments

2nd phase development: inclusion of the wave effect on coastal areas regimes

TECHNICAL ISSUES WG DECIDED TO IMPLEMENT

1. 3D Stokes Drift calculation: According "Approximate Stokes Drift Profiles in Deep Water" Ø. Breivik, P. Janssen, J-R Bidlot. DOI: 10.1175/JPO-D-14-0020.1. JPO;
2. Vertical Turbulence, in addition to TKE implement the Qiao (2010) formulation (works with all the vertical closure schemes);
3. Modify the surface vertical velocity accounting for the Stokes Drift;
4. Include in the tracer advection the Stokes component;
5. Generalization of the surface boundary condition for momentum accounting for the wave effects;
6. Computation of the Stokes-Coriolis Force in both flux and vector invariant form and according the existing schemes + time splitting case

In Branch 2014/dev_r4822_INGV_WAVE

1. Modification of 3D Stokes Drift calculation according to Breivik et al., 2014

$$\mathbf{u}_m = \mathbf{u}_0 \, \mathrm{e}^{2k_m z}. \quad \longrightarrow \quad \mathbf{u}_e = \mathbf{u}_0 \frac{\mathrm{e}^{2k_e z}}{1 - 8k_e z}.$$

$$k_e \approx \frac{|\mathbf{u}_0|}{5.97|\mathbf{T}_{st}|} \qquad \mathbf{T}_{st} = \frac{1}{16}\overline{\omega} H_S^2$$

u_0=surface Stokes drift; K_m=mean wave period; K_e=effective wave number
T_{st}=Stokes transport; H_s= significant wave height; ω =wave frequency

OPA_SRC/SBC/sbcwave.F90

External data: surface Stokes drift, mean period, significant wave height

In Branch 2014/dev_r4822_INGV_WAVE

2. Vertical Turbulence: implemented the Qiao (2010) formulation (works with all the vertical closure schemes):

Evaluate the Qiao enhanved vertical mixing parameter

$$B_v = \alpha A U_s(0) e^{3kz}$$

OPA_SRC/ZDF/zdfqiao.F90

External data: mean wavenumber k

Add Qiao parameter to vertical viscosity and diffusivity
OPA_SRC/step.F90:

$$K_m \rightarrow K_m + B_v \qquad K_h \rightarrow K_h + B_v$$

In Branch 2014/dev_r4822_INGV_WAVE

3. Surface vertical velocity accounting for the Stokes Drift. The Eulerian vertical velocity at the surface is related (Bennis et al., 2011) to the surface height by

$$\hat{w} = \frac{\partial \hat{\eta}}{\partial t} + \left(\hat{\mathbf{u}} + \mathbf{U}_s\right)\Big|_{z=\eta} \cdot \nabla_h(\hat{\eta}) + P - E - W_s\Big|_{z=\eta}$$

$$\hat{w} = \hat{w} + \mathbf{U}_s\Big|_{z=\eta} \cdot \nabla_h(\hat{\eta}) - W_s\Big|_{z=\eta}$$

OPA_SRC/DYN/sshwzv.F90

Ready for branch 2014/dev_r4822_INGV_WAVE

4. Tracer advection

Include in the tracer advection the Stokes components

Add Stokes drift to eulerian velocity in tracer advection

$$\frac{\partial C}{\partial t}+\frac{\partial\left(\hat{u}+U_s\right)C}{\partial x}+\frac{\partial\left(\hat{v}+V_s\right)C}{\partial y}+\frac{\partial\left(\hat{w}+W_s\right)C}{\partial z}=0$$

OPA_SRC/TRA/traadv.F90

Ready for branch 2014/dev_r4822_INGV_WAVE

5. Surface boundary condition for the momentum

$$\tau_{oc} = \tau_a - \left(\tau_{in} + \tau_{dis}\right)$$

$$\tau_{oc} = \tau_a - \rho_w g \int_0^{2\pi} \int_0^{\infty} \frac{\mathrm{K}}{\omega} \left(S_{in} + S_{dis}\right) d\omega d\theta$$

Modify the wind stress accounting for the stress fraction absorbed by the wave (*tauoc_wave* read from wave model), that must be subtracted from the wind stress

SBC/sbcmod.F90

External data:stress fraction absorbed by the wave: tauoc_wave

In branch 2014/dev_r4822_INGV_WAVE

6. Stokes-Coriolis and metric terms + Time splitting

$$\left(fV_s ; \quad -fU_s \right)$$

Implementation of the Stokes-Coriolis force in both flux form and vector invariant form according to the existing numerical schemes and accounting for the curvature metric term for the Stokes Drift when flux form is used.

Implementation of the time-splitting case

2015 WG ACTIVITIES

1) Finalize the developments in the created branch
2) Review the interface for external data (sbc_wave and related namelist)
3) Test the wave related developments on a proper configuration
4) Start discussion on implementation of small-scale coastal processes