Modifications respect to the ECMWF branch to be implemented	***Responsible***
3D Stokes Drift computation: The Stokes is computed in *dyn_stcor* and simultaneously the Stokes-Coriolis force computed and included in the general momentum trend. The Stokes Drift computation should be replaced and the Stokes Drift current becomes a state **public variable** in the *sbc_wave* module, so it can be used also in other terms (tracers and momentum advection). The algorithm proposed to compute the 3D Stokes Drift current is a better approximation than the approximation currently used. The usd3d, vsd3d and wsd3d variables should be computed following the **Breivik** code in sbc_wave.	INGV
Coriolis and metric terms Implementation of the Stokes-Coriolis force according the existing numerical schemes and accounting for the curvature metric term for the Stokes Drift when flux form is used We have to compute: - vector invariant form rotn × u + f × u + f × u_stokes - flux form (f + metric + metric_stokes) × u + (f + metric) × u_stokes (see equation 26-27 of Uchiyama OM 2010 for instance, or 14-15 of Kumar OM 2012) One way to do it may be to call vorticity routines twice with input arguments - vorticity - velocity for metrics - velocity for vorticity For instance CALL vor_een (kt, ntot, rotn, un+ust, vn+vst, un, vn, ua, va) ! usual trend + eventually advection metric including wave CALL vor_een (kt, ntot, 0 , un , vn, , ust, vst, ua, va) ! stokes coriolis Another way may be to add all the different cases and play with kvor inside	Rachid Benshila (if NEMO_st agrees)

the routines.	
Time splitting: The time-splitting case is not implemented. Two parts are missing. First the Stokes-Coriolis contribution should be removed from the general trend during the "coupling" phase. Second the barotropic Stokes-Coriolis term should be introduced in the barotropic loop. Depends on the previous point.	
Advection	INGV
Surface boundary condition for the momentum: The process has been implemented in the ***CORE*** bulk formulation. It should be coded independently from the kind of bulks used and probably placed in ***sbc*** (***sbcmod.F90***). The bulks already implemented in NEMO should be used to obtain a first guess of τ and then the τ should be modified accounting for the wave effect. In this way also the "flux" option (the fluxes as external data) could be included.	
Surface vertical velocity accounting for the Stokes drift: (see Equations 8 and 9 below)	INGV
Implementation of Qiao et al. (2010) formulation accounting for the enhanced vertical mixing induced by waves	INGV

To represent the wave current coupling effect accounting for the full spectra of scales and phenomena the momentum equations are re-written in terms of the quasi-Eulerian velocities $(\hat{u},\hat{v},\hat{w})$ according to Bennis et al. (2011, doi:10.1016/j.ocemod.2011.09.003) where:

$$(\hat{u},\hat{v},\hat{w}) = (u,v,w) - (U_s,V_s,W_s) \tag{1}$$

where (u,v,w) are the mean Lagrangian velocities and (U_s,V_s,W_s) the 3D Stokes Drift in the horizontal (x,y) and vertical (z) directions. They are valid from the bottom $z = -h$ to the local phase-averaged free surface $z = \hat{\eta}$.

$$\frac{\partial \hat{u}}{\partial t} + \hat{u}\frac{\partial \hat{u}}{\partial x} + \hat{v}\frac{\partial \hat{u}}{\partial y} + \hat{w}\frac{\partial \hat{u}}{\partial z} - f\hat{v} + \frac{1}{\rho}\frac{\partial p^H}{\partial x} = \left[f + \left(\frac{\partial \hat{v}}{\partial x} - \frac{\partial \hat{u}}{\partial y}\right)\right]V_s - W_s\frac{\partial \hat{u}}{\partial z} - \frac{\partial J}{\partial x} + \widehat{F}_{m,x} + \widehat{F}_{d,x} + \widehat{F}_{b,x} \tag{2}$$

$$\frac{\partial \hat{v}}{\partial t} + \hat{u}\frac{\partial \hat{v}}{\partial x} + \hat{v}\frac{\partial \hat{v}}{\partial y} + \hat{w}\frac{\partial \hat{v}}{\partial z} + f\hat{u} + \frac{1}{\rho}\frac{\partial p^H}{\partial y} = -\left[f + \left(\frac{\partial \hat{v}}{\partial x} - \frac{\partial \hat{u}}{\partial y}\right)\right]U_s - W_s\frac{\partial \hat{v}}{\partial z} - \frac{\partial J}{\partial y} + \widehat{F}_{m,y} + \widehat{F}_{d,y} + \widehat{F}_{b,y} \tag{3}$$

where the left hand side is the classical primitive equation model for the quasi-Eulerian velocity with:

- ρ the mean density;
- p^H the hydrostatic pressure;
- f the Coriolis parameter;
- $\left(\widehat{F}_{m,x};\widehat{F}_{m,y}\right)$ related to the mixing effects (that redistribute momentum).

The right hand side contains the forcing terms where:

- $\left(\left[\left(\frac{\partial \hat{v}}{\partial x} - \frac{\partial \hat{u}}{\partial y}\right)\right]V_s - W_s\frac{\partial \hat{u}}{\partial z};\ \left[\left(\frac{\partial \hat{v}}{\partial x} - \frac{\partial \hat{u}}{\partial y}\right)\right]U_s - W_s\frac{\partial \hat{v}}{\partial z}\right)$ is the vortex force;
- $\left(fV_s;\ \ -fU_s\right)$ is the Stokes-Coriolis force;
- $\left(-\frac{\partial J}{\partial x};-\frac{\partial J}{\partial y}\right)$ is the force linked to the wave-induced mean pressure J (Bernoulli pressure head) where $J = g\frac{kE}{\sinh(2kD)}$, E is the surface elevation variance, $D=h+\hat{\eta}$ is the water depth, k is the wavenumber;
- $\left(\widehat{F}_{d,x};\widehat{F}_{d,y}\right)$ is the source of quasi-Eulerian momentum that is equal to the sink of wave momentum due to breaking and wave-turbulence interaction;
- $\left(\widehat{F}_{b,x};\widehat{F}_{b,y}\right)$ is the source of quasi-Eulerian momentum that is equal to the sink of wave momentum due to bottom friction (included if the bottom boundary layer is resolved).

Considering the abovementioned representation of the momentum equation, it has been decided to first implement processes occurring from meso-scale to large-scale. The representation of the wave-induced effect in this range involves the introduction of five additional terms in the primitive equations:

1. Stokes-Coriolis force;

$$\left(fV_s; \quad -fU_s\right) \tag{4}$$

2. Surface boundary conditions for the momentum (modification of the wind stress to account the amount of energy stored into the wave field);

$$\begin{aligned} \tau_{oc} &= \tau_a - \left(\tau_{in} + \tau_{dis}\right) \\ \tau_{oc} &= \tau_a - \rho_w g \int_0^{2\pi}\int_0^{\infty} \frac{\mathrm{K}}{\omega}\left(S_{in} + S_{dis}\right) d\omega d\theta \end{aligned} \tag{5}$$

where τ_{oc} is the water-side stress felt by the ocean, τ_a is the air-side stress, τ_{in} is the momentum absorbed by the wave field and the amount released from breaking waves τ_{dis}, K is the wave number vector, ω is the angular wave frequency, θ is the wave direction, S_{in} and S_{dis} are the wind input and dissipation.

3. Transport of active and passive tracers (*C*) by the 3D Stokes drift:

$$\frac{\partial C}{\partial t} + \frac{\partial\left(\hat{u} + U_s\right)C}{\partial x} + \frac{\partial\left(\hat{v} + V_s\right)C}{\partial y} + \frac{\partial\left(\hat{w} + W_s\right)C}{\partial z} = 0 \tag{6}$$

4. Source/Sink term in the vertical turbulence model:

$$\Phi_{oc} = \Phi_{in} - \rho g \int_0^{2\pi}\int_0^{\infty}\left(S_{in} + S_{dis}\right) d\omega d\theta \tag{7}$$

where Φ_{oc} is the energy flux to the ocean column, Φ_{in} is the energy flux from the atmosphere, $\rho g \int_0^{2\pi}\int_0^{\infty}\left(S_{in} + S_{dis}\right) d\omega d\theta$ represents the wave energy flux at the sea surface.

5. Surface vertical velocity accounting for the Stokes drift.
The Eulerian vertical velocity at the surface $\hat{w}$ is related (Bennis et al., 2011, Eq (16)) to the surface height $\hat{\eta}$ by:

$$\hat{w} = \frac{\partial \hat{\eta}}{\partial t} + \left(\hat{\mathbf{u}} + \mathbf{U}_s\right)\Big|_{z=\eta} \cdot \nabla_h(\hat{\eta}) + P - E - W_s\Big|_{z=\eta} \tag{8}$$

where the vertical Stokes velocity at the surface is:

$$W_s\Big|_{z=\eta} = -\nabla \cdot \int_{-h}^{\eta} \mathbf{U}_s \, dz \tag{9}$$

and E is evaporation, P is precipitation.

Regarding the 4th term, there is a general consensus within the enlarged working group members that basic research is still needed. None of the presently available turbulent closure models (TKE, KPP, GLS, Richardson number) correctly deal with the wave induced turbulence. Approximations are available and will be adopted in the first phase (Qiao term or modification of TKE). The representation of non-local effect in KPP have some appeal but it should be reformulated according the wave dynamics.