Notes on NEMO-Wave WG meeting, ECMWF, 13-14 May 2014

J. Wolf, E. Clementi

AGENDA

13 May: 09.30-17.30

From	To	Subject	Presenter
9.15	**9.30**	**Meet at ECMWF Reception**	
9.30	9.40	NEMO-WAVE Working Group	P.Oddo
9.40	10.00	Wave-current interactions in three dimensions: recent progress and challenges	F.Ardhuin
10.00	10.20	Langmuir turbulence in the ocean mixed layer	A. Grant
10.20	11.20	Discussion	ALL
11.20	11.40	Coffee break	
11.40	12.00	Coupled wave-ocean modelling system in the Mediterranean Sea	E.Clementi
12.00	12.20	Overview of the MyWave project and the work on atmosphere-wave-current coupling	O.Saetra
12.20	12.40	R&D on impact of atmosphere-wave-ocean coupling under the MyOcean project	C. Harris
12.40	13.00	Discussions	ALL
13.00	14.30	Lunch	
14.30	14.50	Introducing wave effects in NEMO	O.Breivik
14.50	15.10	Wave - current interactions examples using the Princeton Ocean Model	G.Korres
15.10	15.30	ROMS vs. NEMO	R.Benshila
15.30	15.50	Coupling of wave and circulation models in coastal-ocean predicting systems: A case study for the German Bight	J.Staneva
15.50	16.10	Wave-Current interaction in coastal areas	A.Bruschi
16.10	16.30	Coffee Break	
16.30	17.20	Discussion	ALL
17.20	17.30	Closure of the 1st day meeting	
19.00		Dinner together at Art of Siam	

13 May: 09.30-17.30

From	To	Subject	Presenter
9.30	9.50	NEMO status and ongoing work at INGV	E. Clementi
9.50	10.10	NEMO-ECMWF implementation	O. Breivik/ K.Mogensen
10.10	11.00	Compatibility between the 2 developments? Merging in future NEMO release? Need to generalize the interface?	ALL
11.00	11.30	Coffee break	
11.30	13.00	Discussion on how to implement 1st day outcomes	ALL
13.00	14.30	Lunch	
14.30	15.30	Discussion on how to implement 1st day outcomes	ALL
15.30	15.50	Summary document of the 1st day outcomes	ALL
15.50	16.00	Closure of the 2nd day meeting	

PARTICIPANTS

n.	NAME	INSTITUTION	e-mail	DAY1	DAY2
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23	Magdalena Balmaseda	ECMFW	Magdalena.Balmaseda@ecmwf.int	yes	no

Host: Oyvind Breivik, ECMWF

Chairman: Paolo Oddo, INGV

Day One

Introduction - Paolo Oddo (INGV): NEMO WAVE Working Group

WG Goals:

- explore the way in which surface gravity waves can influence the ocean circulation
- define and coordinate a science based implementation plan to incorporate the wave effect in the NEMO releases According recent NEMO Developers Committee Discussion the target resolution for NEMO is 1km

List of Members of NEMO-wave WG and list of experts. Fabrice Ardhuin asked about the role of the external experts: to help in understanding the wave-current interaction issues.

Preparation of White Paper – 2 versions (i) internal to consortium (ii) for dissemination. It will be shared before next NEMO user meeting .

Participants have been informed about the next NEMO User meeting that will held in Grenoble 7-8 July, and invited to participate. More information here: http://www.nemo-ocean.eu/About-NEMO/News/7-8-July-2014-In-Grenoble-Fance.

1. **Fabrice Ardhuin (IFREMER, CNRS) – Wave-current interactions in 3D: recent progress and challanges**
   - Adiabatic 3D wave-current interaction theory: review of background theory on different momentum equations formulated for total momentum and mean flow momentum in 2D and 3D. Depth integration. McWilliams analytical theory showing Eulerian vs Langrangian quoting Lane et al (2007). Mellor (2003, 2008) presents an inconsistent approximation for the vertical flux <p ds/dx>. Strong shear of drift in nearly breaking waves (Miche, 1944).
   - Coastal applications: Delpey et al (2014) case study on St Jean de Luz Bay – effect on tracers, strong haline stratification and bacteria. 2D and 3D model results are very different. Sunglint images from MERIS show changes in roughness/slopes at fronts – want to infer current field from images.
   - The mixing challenge: Effect of waves on mixing is important for marine energy.
   - Why wave model parameterizations matter. New version of ECMWF with WW3 – different wave spectrum tail – effect on Stokes drift can be substantial – discussion about buoy error, spectrum tail of spectrum. Stokes drift in nonlinear waves can be larger than in linear.
   - Waves and sea ice; waves in sea ice model are still very primitive (progress under way)

2. **Alan Grant (U Reading) – Langmuir turbulence in the ocean mixed layer**
   Problem with turbulence in the ocean mixed layer: vertical velocity variances observed from Lagrangian floats are larger than expected for a classical turbulent flow but are consistent with LES (Large Eddy Simulations) including parameterized Stokes drift. Stokes shear tilts and stretches vortices: this is believed to be the origin of Langmuir circulation and can be represented as a vortex force.

Shear production feeds energy into horizontal turbulent flow, Stokes effect feeds into vertical component. Stokes production is main term and its effect is felt throughout the mixed layer. It entrains cold water into mixed layer, so the mixed layer grows downwards. Parameterisation into e.g. 1st order scheme such as KPP. Examine <u’ w’> for various values of Langmuir number (u_*/u_s). Effect of inertial oscillations are apparent at base of mixed layer, little effect higher up. Momentum transport can be parameterised using flux-gradient relationship including Stokes term. Effects of swell are different depending on direction of winds. Full wave spectrum may be difficult to model but may give similar results. Discussion – Breivik: sceptical about relative importance of shear vs Stokes, Grant: effect of wave breaking is difficult to resolve, very near-surface and dissipated near surface. Damping of waves?

3. **Discussion**
   Oddo: how to move forward with NEMO – vertical or horizontal term?. Which choice e.g. if we use vortex force formalism (Rachid). 1st steps have been taken in modification of vertical mixing. Comments by Ardhuin – we do not have correct equations for total momentum, so only option is vortex force formalism. What is the way forward? Grant suggests to use 1D in vertical as first step. The general assumption, for large-scale modelling, is that vertical scales are much smaller than horizontal but it may be different in high-res applications. Staneva: radiation stress vs vortex force – which works better? depends on application, radiation stress much easier to implement. Ardhuin: if everything uniform in horizontal, vertical flux vs radiation stress should be the same. Staneva: near coast these issues become important - horizontal scales much smaller and bottom gradients larger.

4. **Emanuela Clementi (INGV): Coupled wave-ocean modelling system in the Mediterranean Sea**
   (i) 2-way coupling through Cd - Improvements in waves, no effect on currents. (ii) 1-way Qiao wave-induced mixing improves model skill compared to satellite SST, S&T ARGO profiles. Some differences between different sea areas. Discussion – apparent wind, Tolman physics, why are we getting such results, better physics or compensating for errors in winds?

5. **Oyvind Saetra (MET NO): MyWave**
   MyWave has been established to complement MyOcean but with no operational deliverable. WP1: Model developments led by Peter Janssen – wind input in extreme conditions, wind-wave interaction in swell conditions, improved nonlinear transfer, improved wave breaking, coupling with ocean, development of regional models (Italy, Greece), web-based source code library. Momentum transfer through surface waves – Stokes drift not properly represented in Eulerian coordinates. Waves may be regarded as intermediate storage of momentum, transported to another location before breaking and releasing momentum again. WP2: data assimilation, improved use of nearshore remote sensing data, connecting large-scale forecasts to near-shore. WP3: Ensemble forecasting e.g. Barcelona harbour. WP4: Metrics – triple collocation, user-focussed performance metrics, metrics for ensemble. How to move towards Marine Core Service for waves – Road Map.

6. **Chris Harris (METOFFICE): MyOcean2 wave coupling**
   Harris is managing Short-Range Coupled Forecast Development group at Met Office: coupled atmos-ocean system already providing global products for MyOcean2; now want to include

waves; Met Office leads global wave coupling work in MyOcean2 (WP19.4.1). There are links between MyOcean and MyWave projects. MyOcean WP19.4.1 concerns wave coupling for the global ocean: ECMWF working on Stokes-Coriolis effect, wave modified surface stress and drag, wave induced mixing; METOFFICE working on wave modified drag and wave induced mixing. MyOcean2 WP19.4.2 concerns different actions related to wave coupling for regional seas, e.g.: development of software for additional parameter to be exchanged, integrate/substitute new developed coupling components.

7. **Oyvind Breivik (ECMWF): Introducing wave effects in NEMO**
   (i) Stokes-Coriolis (ii) Wave-modified stress and drag, evaluation of the drag coeff through the Charnock coeff., the CD is stored as CDWW in ERA-Interim (iii) TKE with sea-state dependent energy flux, Craig and Banner (1994) related the TKE flux PHIOC to the wind stress; the parametrer PHIOC is stored in ERA-interim. Recent paper shows differences in global model introducing these terms. Substantial reduction of SST bias. Improving TKE model by implementing wave breaking TKE as source term in TKE equation rather than at surface. Results suggest that the Stokes shear is too weak to make a difference to the mixing. Comment from Grant: TKE closure is bad, need full Reynolds stress tensor (9 terms). Using TKE equation for Langmuir turbulence does not work. Need length scale/dissipation rate to change dramatically near-surface (length-scale associated with turbulence).

8. **Gerasimos Korres (HCMR): Wave - current interactions examples using the Princeton Ocean Model**
   Wave model parameters needed by the hydrodynamic: surface Stokes drift, dissipated wave energy at the surface, stress at the surface.
   Model performances with idealized cases: Sensitivity tests – alongshore strip, 5m resolution, different profiles, plane beach, curved shoreline, canyon.
   Model performances with real test cases WAM+POM in the Aegean Sea: (1/30x1/30). Vertical mixing from (1) Qiao et al (OD, 2010) (2) TKE at surface (3) wave dissipation introduced as TKE (Janssen, JGR, 2012), (4) Huang & Qiao (2010). Tests 2, 3 & 4 give similar results. Method 1 could be an easier alternative for large to medium scale models especially if they are not solving a TKE equation. Future steps: 1) Investigate how the combination of approaches 3 & 4 (wave breaking & wave – turbulence interactions) performs; 2) Study the wave dependent bottom fiction. Upper ocean vertical mixing important for small and large scale applications.

9. **Rachid Benshila (CNRS): ROMS-AGRIF – Applicaton to a rip-current**
   Waves as an interface to study extreme events, interest in near shore dynamics, problems linked to coupling at different scales and social impacts of extreme events. Rip currents case study, Biscarosse beach, 4 days observations. Used ROMS-AGRIF and a simplified WKB wave model that is easy to use and valid for near shore. Calibration carried out through video as a proxy for breaking. Validation of wave model and circulation with observations

10. **Joana Staneva (Helmholtz-Zentrum Geesthacht): Coupling of wave and circulation models in coastal-ocean predicting systems: A case study for the German Bight**
    Model used: WAM-GETM-GOTM-SPM. 3D radiation stress: Mellor (2008, 2011, 2013), Kumar et al (2011), Vortex force: Ardhuin et al (2008), Bennis et al (2011). Examine storm Xavier, Dec

2013, Britta 1 Nov 2006. Also tested NEMO 3nm for North Sea, looks better than GETM but needs wetting and drying to be implemented. Aim for 3-way coupling.
Impact of hydrodynamics on WAM: Significant impact in the shallow water areas near the coast and in the Wadden Sea. Impact of waves on the GETM results: significant impact in the shallow water areas near the coast, in the Wadden Sea. In tidal inlets, during extreme events the impact of coupling leads to more realistic simulations; both radiation stress and vortex force methods show reasonable results for the shallow German Bight area, but more analyses are needed for the near-coast ´simulations. Impact of wave forcing on the SPM dynamics : better agreement with observations once wave dynamics is included in the SPM coupled system.

11. **Antonello Bruschi (ISPRA): Wave – current interaction in coastal areas**
Deals with higher resolution models close to the coast (grid cell size ranging from 1 m up to about 100 m). Note diffraction must be considered for coastal applications, O(100m). Wave spectral models (WAM, SWAN) does not solve diffraction properly (diffraction not included in their formulation or included in a simplified way). River plume interaction with waves – quite different coupled vs uncoupled. Also including structures. Underestimation of model wave height must be taken into account when analyzing results of wave effects on currents. The interaction between waves and currents is two way. Waves are modified by the currents as much as currents are modified by waves. A correct representation of the phenomenon should be based on this mutual interaction. The trend in coastal engineering is to develop integrated models for both waves and currents.

Day Two

1. **Emanuela Clementi (INGV) State of the Art & Ongoing work at INGV**
NEMO state of the art includes drag coefficient read from wave model output; evaluation of the 3D Stokes drift and vertical component, this is just evaluated but not used in the code.
Discussion on vertical component of Stokes drift (NB Ardhuin says it is implemented in MARS, SYMPHONIE). Nurser says it will in general give a non-zero surface value.
The depth profile for the 3D Stokes drift in NEMO is presently evaluated through the monochromatic approximation. It has been agreed to modify it according to the formulation in Breivik et al. (2013).
INGV ongoing work: account for the wave induced vertical mixing according to Qiao et al. 2010 to modify the vertical viscosity and diffusivity parameters:
Code modifications:
/SBC/sbcwave.F90
step.F90
new routine ZDF/zdfqiao.F90

2. **Øyvind Breivik (ECMWF): The ECMWF NEMO wave physics branch**
Andrew Coward has uploaded the code modifications as a branch in the Paris repositories.
Stokes-Coriolis force: new code in DYN/dynstcor.F90, it reads ERA-Interim parameters in SBC/sbcwave_ecmwf.F90
Wave-modified stress and drag: code changed in SBC/sbcblk_core.F90 and routine added to SBC/sbcwave: sbc_wave_tauoc.F90

Discussion on drag in sea ice (Aksenov). Main point is to supply a surface drag coefficient where there may be a mis-match at the ice edge. Discussion on difference between total stress supplied to ocean and that stored in wave field (integral of Sin + Sds). Mostly these will be differences of a few percent. Ardhuin: we do good balance of energy, not so sure about momentum.

TKE with sea-state dependent energy flux: Craig and Banner modified to allow for varying wave field. Code change in ZDF/zdftke.F90

2 ECMWF technical reports available by Janssen (2013) and Breivik (2013). http://tinyurl.com/ecmwf712 and http://tinyurl.com/ecmwf716 (latter under preparation for JPO).

Andrew Coward has uploaded the wave physics as a branch in the Paris repository: svn+ssh://forge.ipsl.jussieu.fr/ipsl/forge/projets/nemo/svn/branches/2014/dev_r4642_WavesWG

Kristian Mogensen has uploaded 1◦ × 1◦ latitude-longitude WAM forcing fields from ERA-Interim to Archer for the period 1979-2013. These can be used for on-the-fly interpolation in NEMO. The data have also been uploaded to (thanks to Andrew Coward): http://gws-access.ceda.ac.uk/public/nemo/forcing/ECMWF_waves/regular/

Debate on sharing and supporting code, which version. Could tidy up but not robust. Enstrophy and energy. Remove temporary variable? Missing Stokes drift effect on tracers. Boundary condition for vertical velocities, Ardhuin: need bc for Lagrangian or quasi-Eulerian velocity.

Harris: Met Office more interested in coupled mode, presently through OASIS, SBC_couple. INGV and ECMWF presently focussing on forced model. Harris: Any fields required, may be read in forced mode, calculate in coupled, not always same fields. Need smart way to handle fields rather than read or define many times.

3. Discussion on day 1

Oddo and Ardhuin: crude representation of Stokes drift – fix by Breivik, don't want to import whole 3D wave data array, use parameterisation. Vertical mixing: Grant working on better formulation, parameterise how mixed layer varies, modified KPP, or modified TKE not really advisable. How to move forward? Oddo: assumed preferred option was to use modified TKE scheme. Can we address large-scale deep ocean first, then tackle coastal processes later? Ardhuin recommends vortex force implementation, comparisons have been done. Benshila: separation between conservative and non-conservative terms, latter may be problematic. Nurser: at least 3 derivations of vortex force available. Mass issue (Nurser), need active tracer. Mogensen: need changes to be implemented asap, at least interface for sharing fields. Coward: merging code does not take the time, but testing does. Coward suggested NEMO-waves is 2-year development plan, year 1 = implement (already done), year 2 = tidy up. Nurser: OSMOSIS mixing model, based on Grant ideas, intention to implement in NEMO. Merge 2 versions then merge into trunk. Inconsistency – Stokes advection missing. Discussion on scales. What is local scale? Staneva: depends on application, previous version of NEMO in Black Sea. Nurser: scale at which Coriolis effective ~ 10km. Boundary condition? Could use depth-integrated, Flather bc, but use Eulerian or Lagrangian velocity. Discussion on test cases.

Benshila comment after the meeting: about vertical mixing, at short term it may be good to discuss with P. Marsaleix about the work done in Symphonie for TKE, since its implementation (without wave) is very close to NEMO's. At longer term, the way to introduce wave effects in

TKE/GLS family will differ to the one for KPP, there should be some work done at Mercator to resurrect KPP in NEMO.

4. **Oddo summarised issues.**
   Contents of the summary is included in the NEMO_WAVE_discussion document.