Chapter 3

Examples

3.1 WEC

This example is of a wave traveling eastward in a narrow channel. The theory is taken from [McWilliams et al.(2004)McWilliams, Restrepo, and Lane]. An analytical model was created and verified for the Wave Effecting Current (WEC) forcing, as documented in Delphine Hypolite's 'Wave_Packet.pdf' and supporting documents, which can be found in the ROMS cloud-drive: 'Model_examples/WEC/Analytical/Wave_packet_scripts'.

This section outlines important details that need clarity for the coding of the WEC module in wec_frc.F, so that it is easier for the next person to understand the implementation.

In wec_frc.F:
cff2= (dble(i)+dble(iSW_corn)-1) * dm_u(1,1) ...

This is because the domain problem is from 0m - 1400m, and u-point node numbering starts from 1. So for the western node 1 the coordinate is 0m. Therefore -1 is needed for cff2 as above.

3.1.1 Grid convergence study

An error analysis was done in the region 150m either side of the center of the wave, because the full domain was very large, but also to ignore the effect of the free wave that could not be reduced further (see free wave in Figure 3.2).

We see in the following figure the results for a grid resolution of $\Delta x = 1m$ and wave height parameter $A = 1e - 3$.

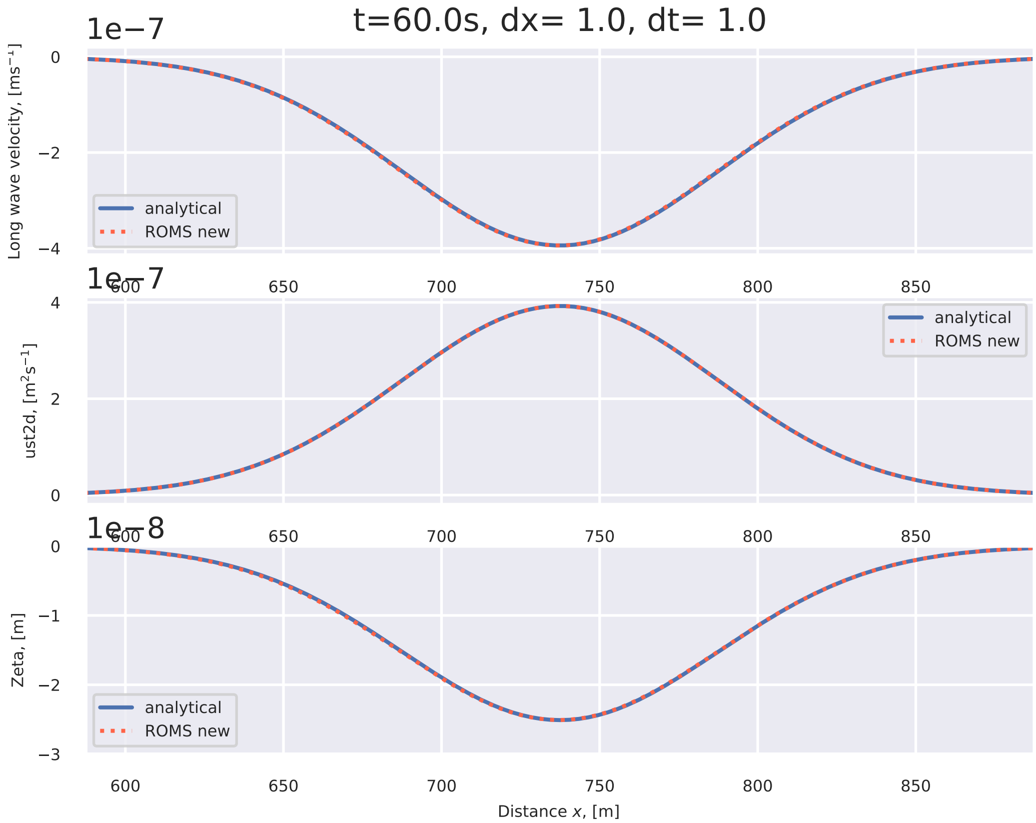


Figure 3.1: Graph of u^{lw}, $\bar{u}$ and ust2d for the immediate region of the wave packet at $t = 60$s, $\Delta t = 1$s, $\Delta x = 1m$, and $A = 1e - 3$.

A grid convergence study was done for a time-step $\Delta t = 1.0$s, $A = 1e - 3$, for various grid spacing of $\Delta x = 1, 2, 4, 8, 20 \,\&\, 25$m. Note the wave amplitude was kept extremely small to reduce the influence of non-linear terms. The code used, the results, and scripts to post-process the results can be found in the ROMS-cloud:
'Model_examples/WEC/Analytical/Convergence_results/'.

The models can be run and all post-processing done simply by running

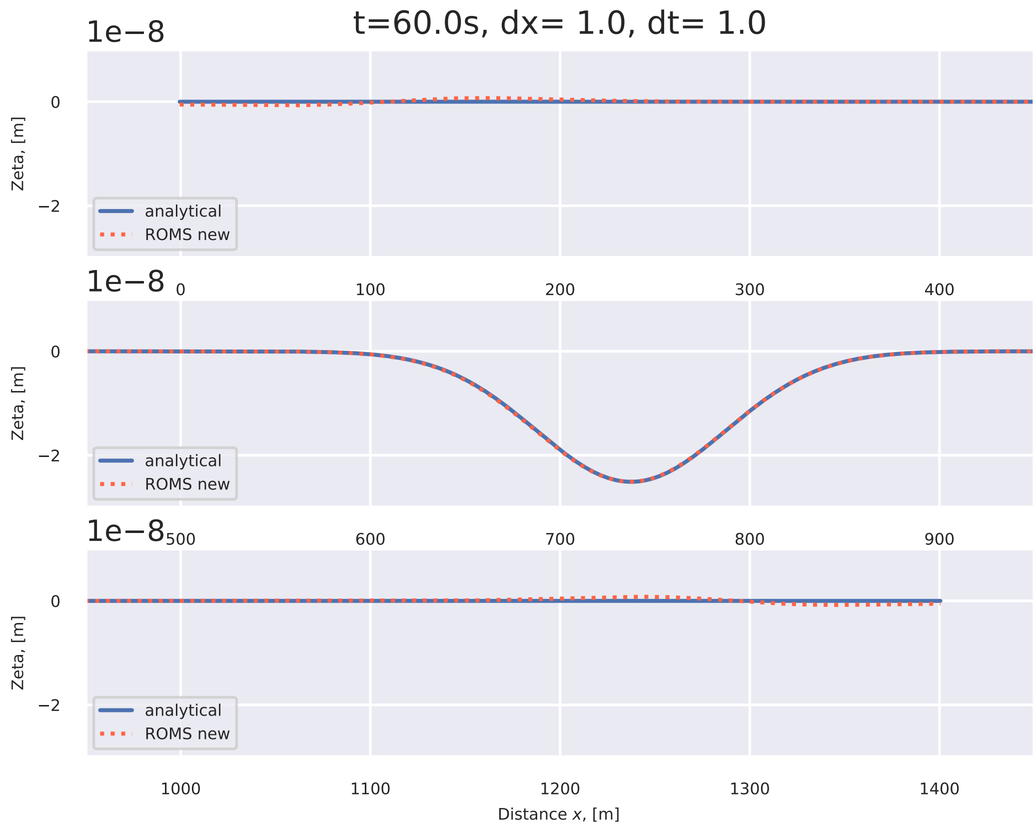
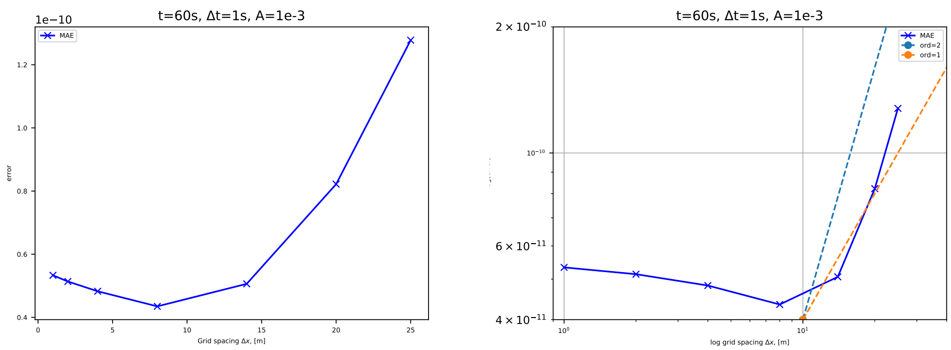


Figure 3.2: Graph of the sea-surface elevation change ζ over the entire model domain for $t = 60$s, $\Delta t = 1$s, $\Delta x = 1m$, and $A = 1e-3$. Note: a free-wave generated by differences in the initial conditions and forcing conditions of $t > 0$ can just be seen on either end of the domain at this time-step. The time step was specifically chosen to avoid the interference on the wave packet against the analytical solution.

the bash script found in that folder: 'WEC_analytical_test_error_script.sh'. This script runs the simulation, runs ncjoin to join the result netcdf files, deletes the grid files, and runs the python script for post-processing of graphs and error results. The python script is in the ROMS-cloud folder called wave_packet_offline.py and it relies on the modules in the folder 'pymodules'. You would also need to install numpy, pylab and matplotlib (if not more).

The results of the grid convergence can be seen in Figure 3.3.



(a) Grid size vs error

(b) log-log of Grid size vs error

Figure 3.3: Grid convergence study for $\Delta t = 1.0$s, $A = 1e-3$, for various grid spacing of $\Delta x = 1, 2, 4, 8, 20 \,\&\, 25$m. The error metric was mean absolute error for all rho-points 150m either side of the center of the wave. For the log-log graph the idealized line for order 1 and 2 convergence was included for reference. The simulation did not solve for $\Delta x > 25m$.

It can be seen for even low resolution ($\Delta x = 20$m) plot that the model still agrees well with the analytical solution, as per Figure 3.4.

Similarly, a grid convergence study was done for wave height parameter $A = 1e-2$. The results for this can be seen in Figure 3.5. Note, $A = 1e-1$ did not give decent results.

3.1.2 Time-step convergence study

As with the previous section, a time-step convergence study was done for a grid-spacing of $\Delta x = 1.0$m, $A = 1e-3$, for various time-steps of $\Delta t = 0.1, 0.25, 0.5, 0.8, 1, \& \,2$s. Note the wave amplitude was kept extremely small

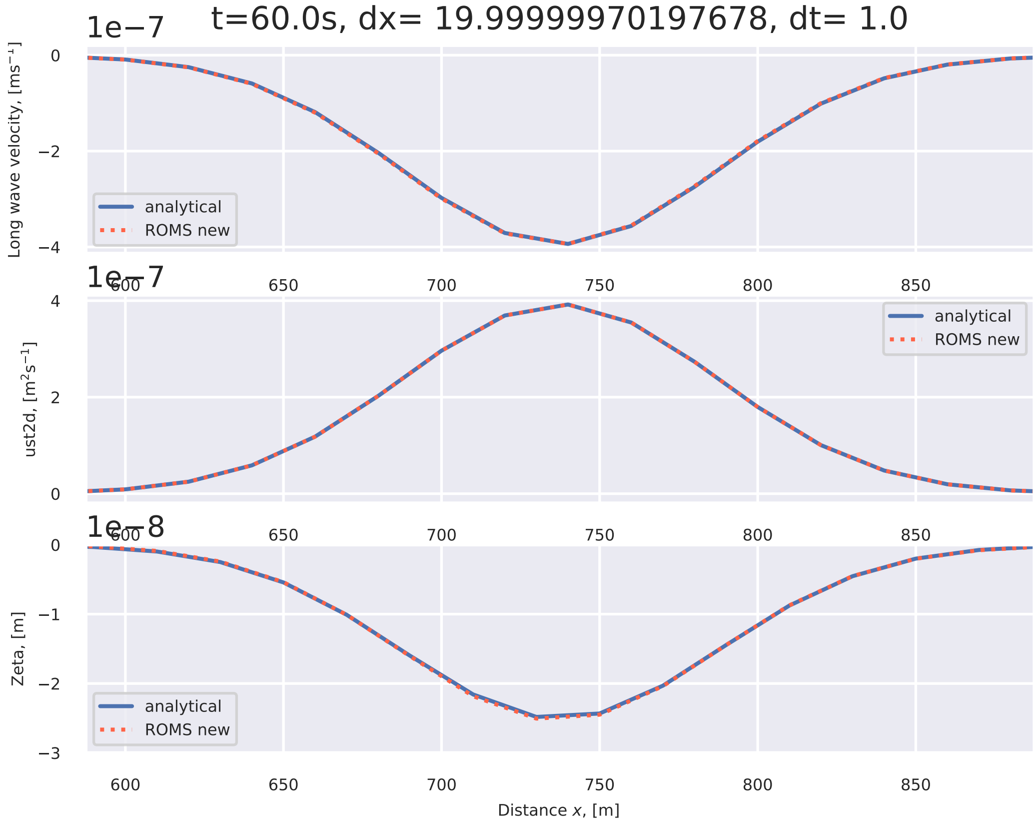
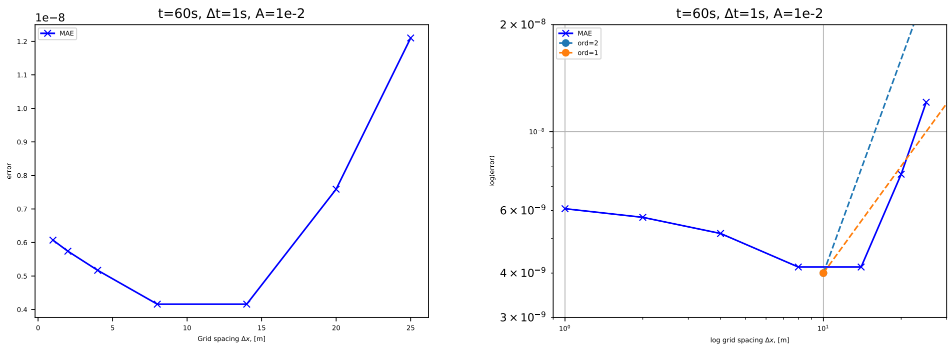


Figure 3.4: Graph of u^{lw}, $\bar{u}$ and ust2d for the immediate region of the wave packet at $t = 60$s, $\Delta t = 1$s, $\Delta x = 20m$, and $A = 1e-3$.



(a) Grid size vs error

(b) log-log of Grid size vs error

Figure 3.5: Grid convergence study for $\Delta t = 1.0$s, $A = 1e - 2$, for various grid spacing of $\Delta x = 1, 2, 4, 8, 20 \,\&\, 25$m. The error metric was mean absolute error for all rho-points 150m either side of the center of the wave. For the log-log graph the idealized line for order to convergence was included for reference. The simulation did not solve for $\Delta x > 25m$.

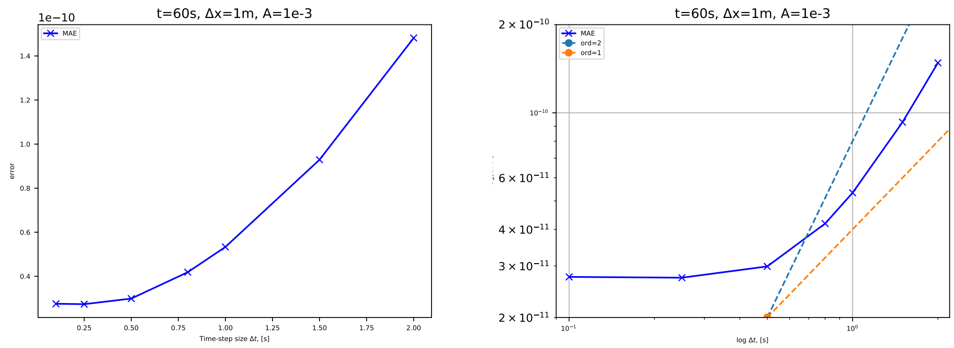
to reduce the influence of non-linear terms. The code used, the results, and scripts to post-process the results can be found in the ROMS-cloud: 'Model_examples/WEC/Analytical/Convergence_results/'

The results of the time-step convergence can be seen in Figure 3.6.

3.1.3 Error calculation notes

Error is of a mean value and not a single value, and I've read in places single values can give higher order convergence that mean values.

sample area changes slightly due to coarseness of grid. The idea is to get the error sample 150m either side of the center of the wave. This is easy for dx ¡= 1m, but beyond i.e. dx = 20m could sit as much as 10m either side of that and change the sample domain. This could be fixed with interpolating node values, but I didn't go to such detail. I can if you think it's important. I just used the nearest node, again only an issue for coarse grids.



(a) Time-step size vs error

(b) log-log of Time-step size vs error

Figure 3.6: Time-step convergence study for $\Delta x = 1.0$m, $A = 1e - 3$, for various grid spacing of $\Delta t = 0.1, 0.25, 0.5, 0.8, 1, \& \, 2$s. The error metric was mean absolute error for all rho-points 150m either side of the center of the wave. For the log-log graph the idealized line for order to convergence was included for reference. The simulation did not solve for $\Delta t > 4s$.

3.1.4 Unresolved issues

The 3d stokes drift (ust) seems to have no affect on the analytical example, as ust is coded to be non-uniform vertically, yet u-3d (u) is vertically uniform and hence $u_{s=i} = ubar$. This is not very intuitive and suggests that the detail of ust is not included in the equation system (only ust2d?), which is an undesirable simplification if that is the case. This result was verified by multiplying ust by a huge number such that ust*1e6, yet the solution remained essentially unchanged.