Coupled Ocean-Wave Models for Galway Bay

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Abstract

Operational ocean and wave models are used to produce forecasts for navigation but also required for a wide range of services, most of them relying on particle tracking methods. Improving the forecast capabilities and accuracy of a model is then a constant necessity in order to deliver more reliable services. The Marine Institute in Ireland is running several coastal operational models, one of them focuses on the area of Galway Bay in the west coast. At the moment it consists of a stand-alone ocean application, it is the purpose of the work presented here to set-up a coupled application with a wave model. Coupled models are a recent development in ocean modelling, developer teams have included ocean and wave coupling by combining existing models each dedicated to a specific physics. Two theoretical formulations are mostly used for the implementation, both giving the same equations of evolution and interaction terms known as the vortex-force formalism. One approach is using a Lagrangian framework defining an exact averaged operator following the fluid particles, the other approach is Eulerian making use of a multi-scale expansion. In both cases the larger current components are found to be forced by gravity and infra-gravity waves. The Coupled Ocean Atmosphere Wave Sediment Transport (COAWST) modelling system is a widely used code, the vortex-force formalism has been implemented in 2012 coupling the Regional Ocean Modeling System (ROMS) with the Simulation Wave Nearshore wave model (SWAN). The implementation has been validated with academic cases and used in several real case studies in the last decade. The work presented here is making use of COAWST, a coupled model is set-up for Galway Bay running a 1-year hind-cast application for 2017 and preliminary results are shown here. The performance of the coupled model is compared with each stand-alone model, using in-situ data as a reference. In the last releases of COAWST the wave model WAVEWATCHIII has been added and can be used in the coupled system. This new feature is tested and the results are compared against SWAN, both wave codes are solving the same equations but different technical choices have been made resulting in different capabilities.

A Coupled Ocean-Wave Model for Galway Bay, Ireland

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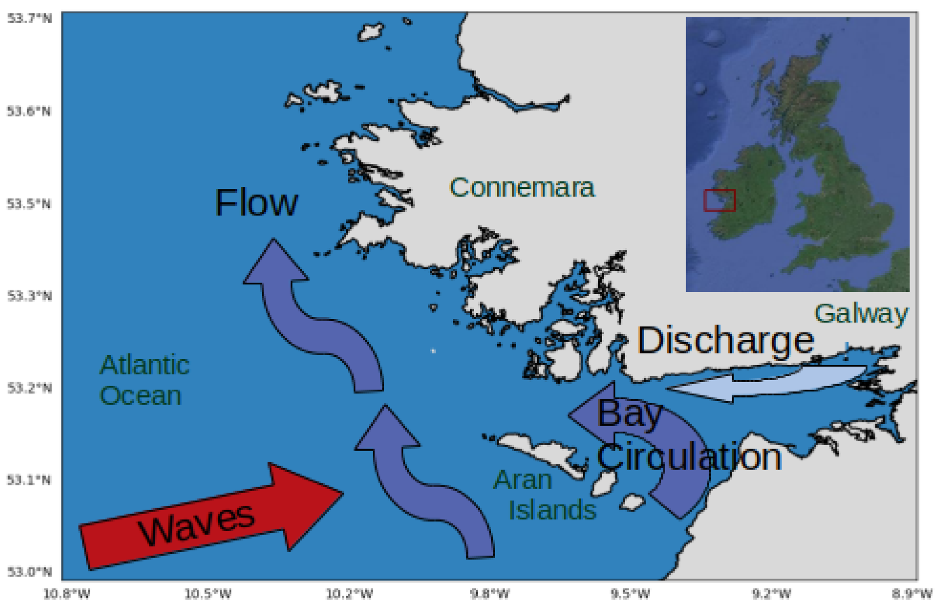
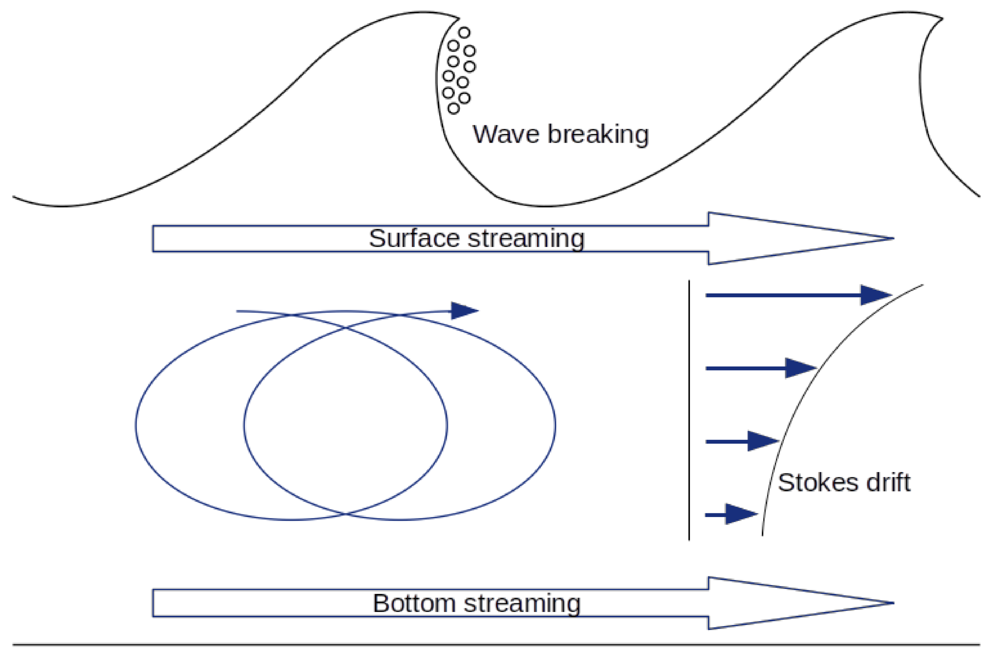
Background and Motivation

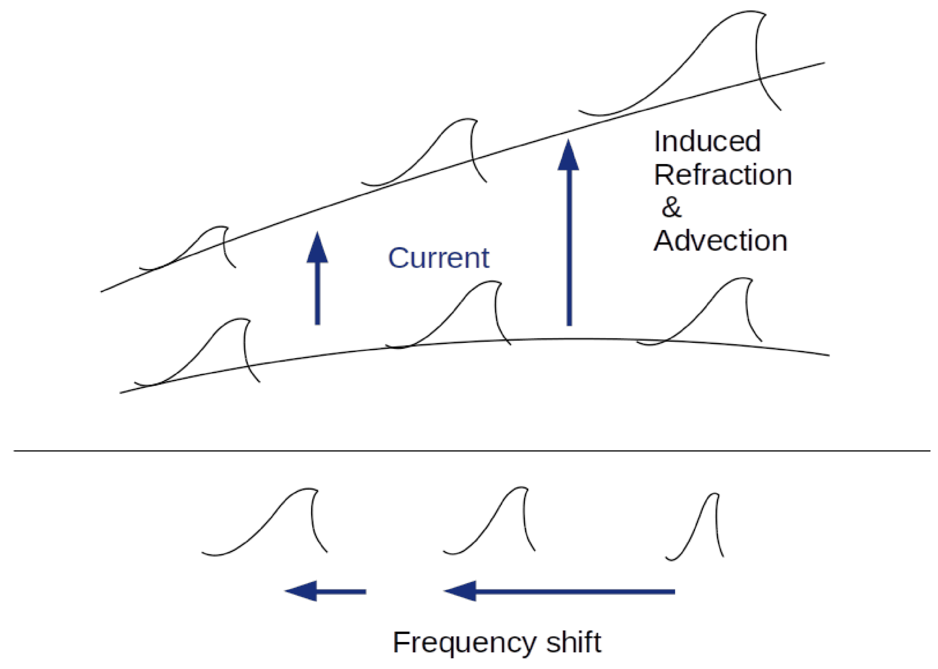
Characteristics of Galway Bay [1]:



Waves effects on current:



Current effects on waves:



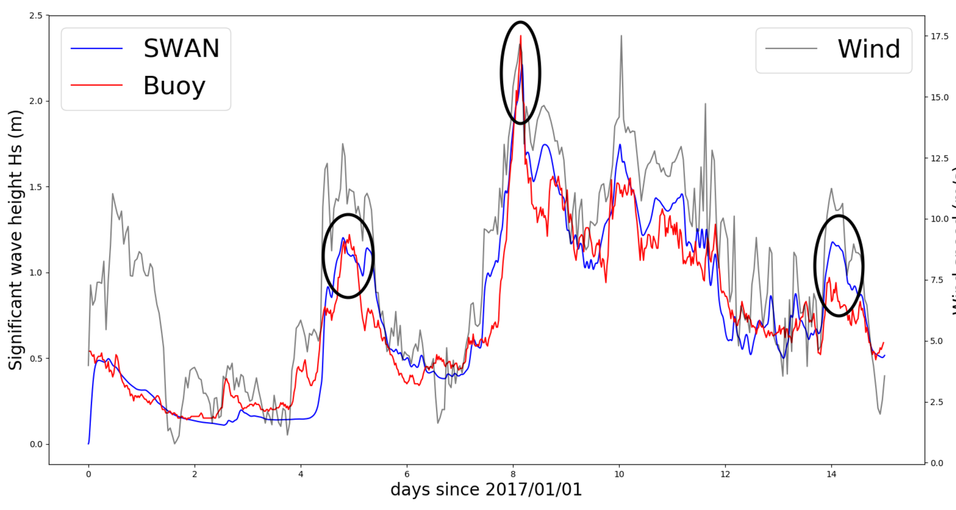
Is it possible to improve the forecast capabilities using a coupled ocean-wave model [2], especially inside the Bay?

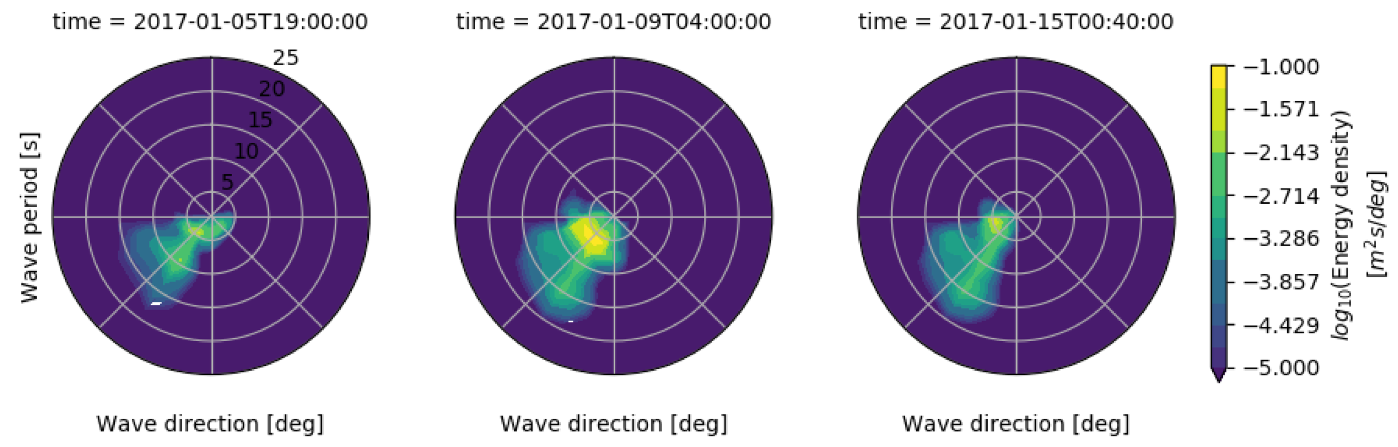
Early results

SWAN standalone

- ▷ Time series of Hs at the wave buoy location
- ▷ Wave spectra at circled times

Wind-sea waves are more important than swell inside Galway Bay.



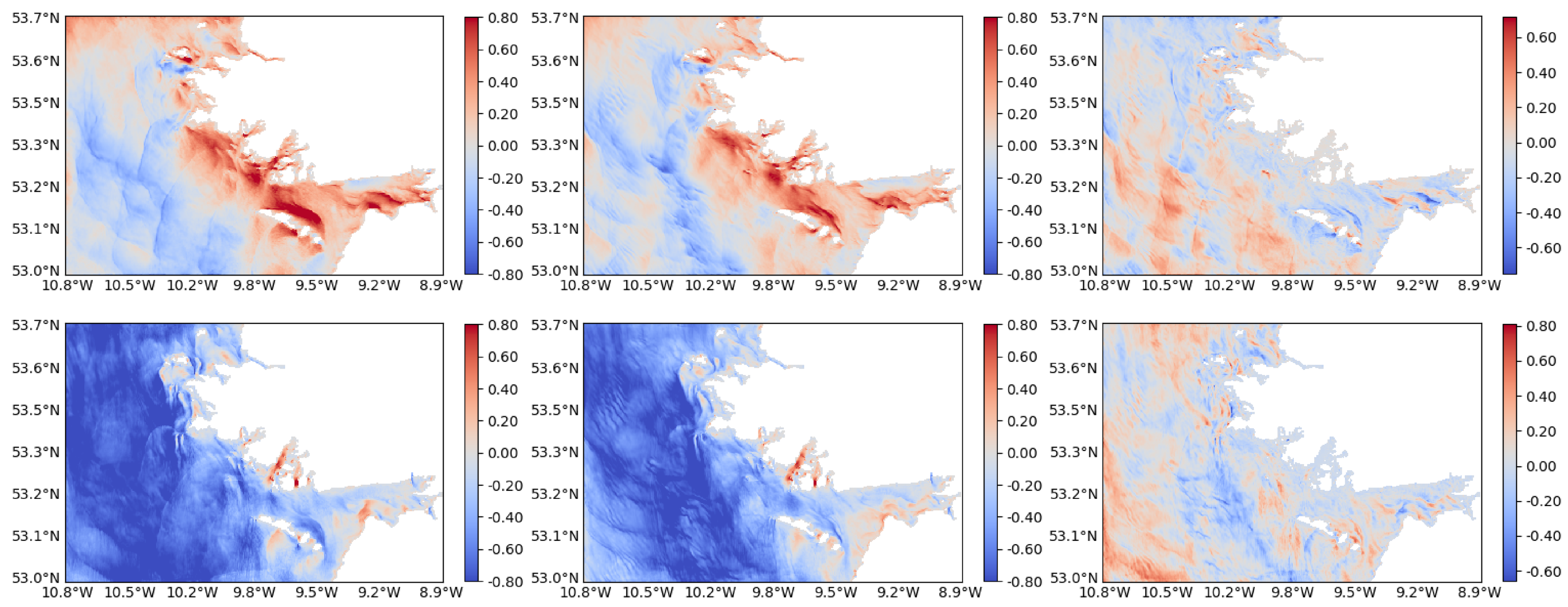


ROMS-SWAN coupled

- ▷ Snapshots at $t = 8$ days of eastward (top) and northward (bottom) surface current velocity (m/s)
- ▷ ROMS standalone (left), coupled model (middle), difference (right)

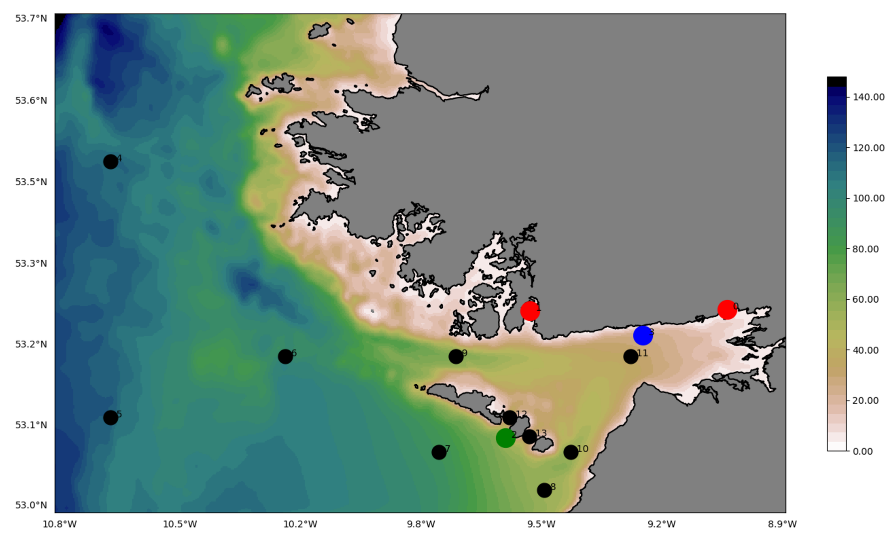
Waves can strongly interact with the current, even inside the Bay.

Future work will include the impact on floater trajectories.



Coupled model - with Coupled-Ocean-Atmosphere-Wave-Sediment Transport (COAWST)

Grid	Curvilinear grid (200mx200m) (640ptx440pt)
Bathymetry	INFOMAR and GEBCO - 20 levels
Forcing	Ocean boundary from model (Marine Institute) (10min)
	Wave boundary from own model (WAVEWATCH III®) (10min)
	Atmospheric forcing from MÉRA (Met Éireann) (1hr)
	River climatologies (1day)
Hindcast period	2017/01/01 to 2017/01/16 - 15s/300s time-step



Bathymetry and location of stations:

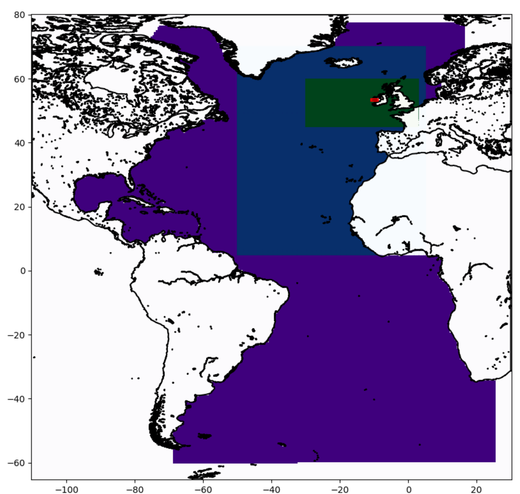
- ▷ Red: tidal gauges
- ▷ Blue: wave buoy
- ▷ Green: ADCP [3]
- ▷ Black: simple output

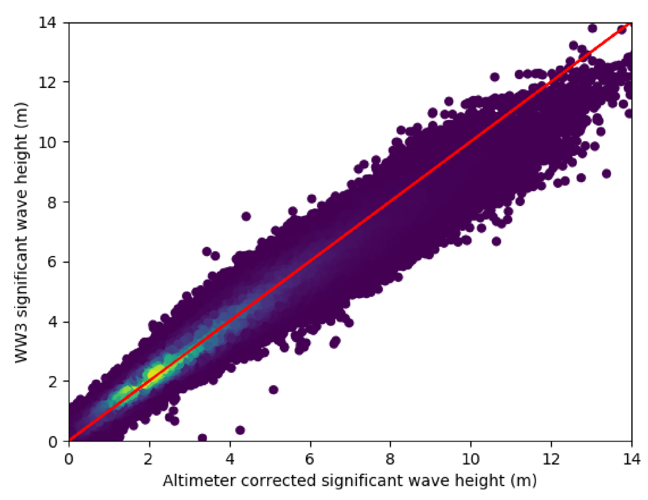
Ocean: Regional Ocean Modelling System (ROMS), computes the current u with forcing and mixing terms $\mathcal{F}, \mathcal{D}$ $\quad \partial_t u + u \cdot \nabla u = \mathcal{F} + \mathcal{F}_w + \mathcal{D} + \mathcal{D}_w \rightarrow U, h, \zeta$

Waves: Simulating Waves Nearshore (SWAN), computes the wave action spectrum A with source and sink term S $\quad \partial_t A + \nabla_x (U + c_g) A + \partial_\theta c_\theta A + \partial_\omega c_\omega A = S/\omega \rightarrow H, \omega, k$

Generation of the wave boundary conditions - Atlantic model

Regular Grids	(0.50°x0.50°) (0.10°x0.10°) (0.05°x0.05°)
	34 freq from 0.0373 Hz - 32 dir bins
Bathymetry	GEBCO 2019 (0.5')
Forcing	Atmospheric forcing from ERA5 (1hr)
	Sea level & current from CMEMS (1day)
Hindcast period	2016/01/01 to 2018/01/01 - 300s time-step





WAVEWATCH III® model

- ▷ Scatter plot of Hs
  Model against altimeter data
- ▷ Extreme waves are underestimated
  A common issue with ERA5

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