PML Plymouth Marine Laboratory

Listen to the ocean

How PML modelling can contribute to understanding the fate of oil spills

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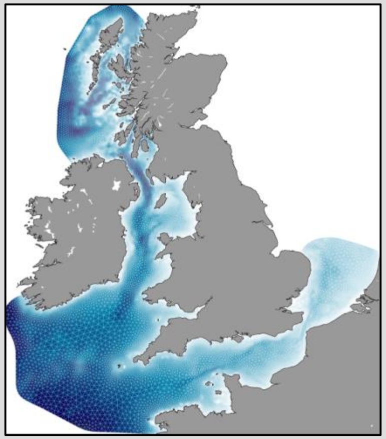
Marine Ecosystem Models & Predictions

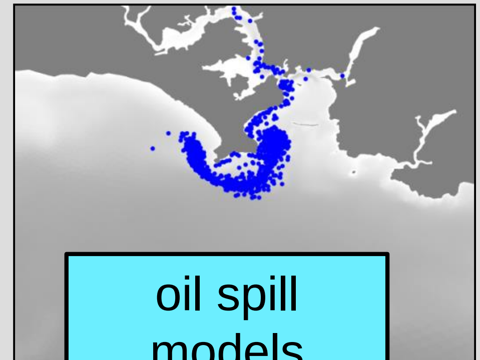
PML modelling capacity

high resolution hydrodynamics



FVCOM

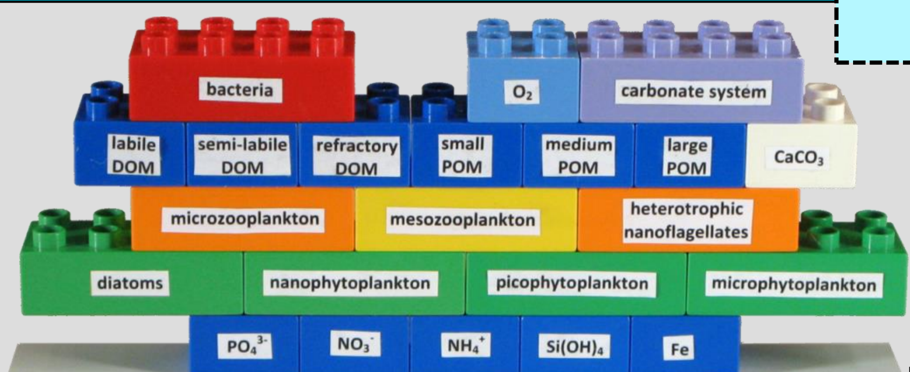
particle tracking



oil spill models e.g., OSCAR

PyLag

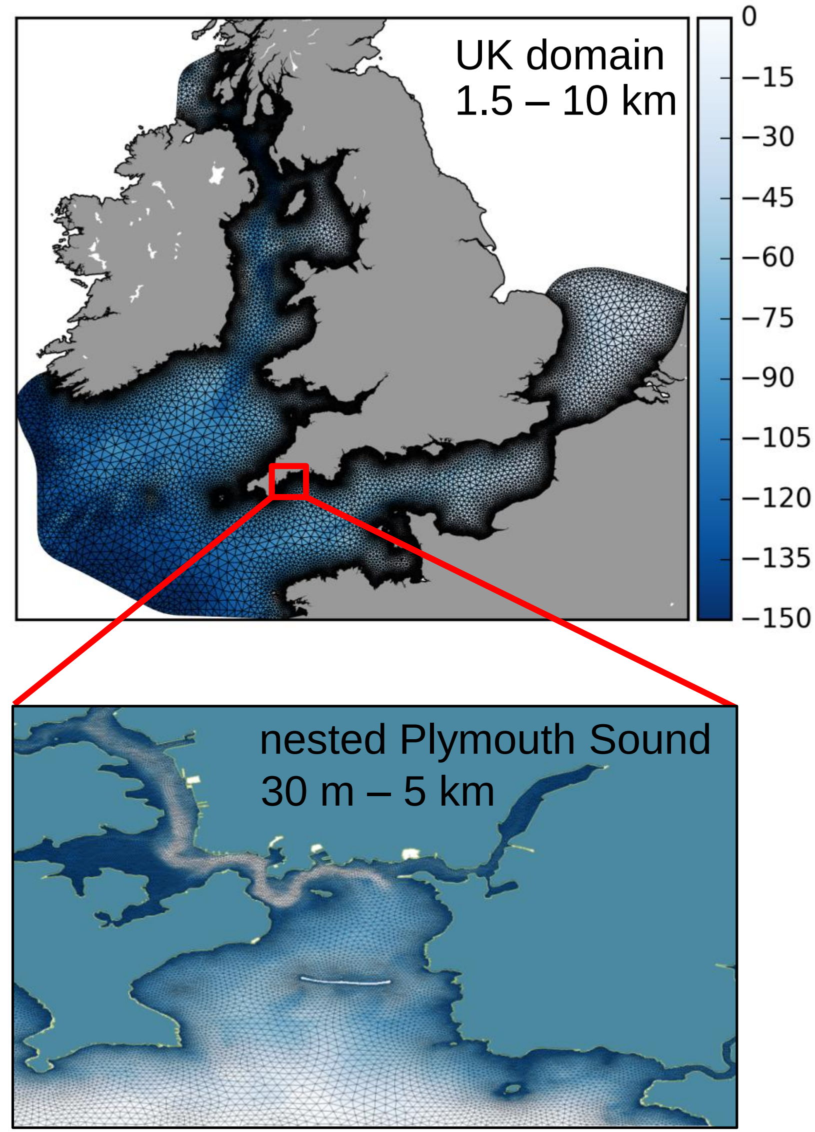
modular ecosystem model



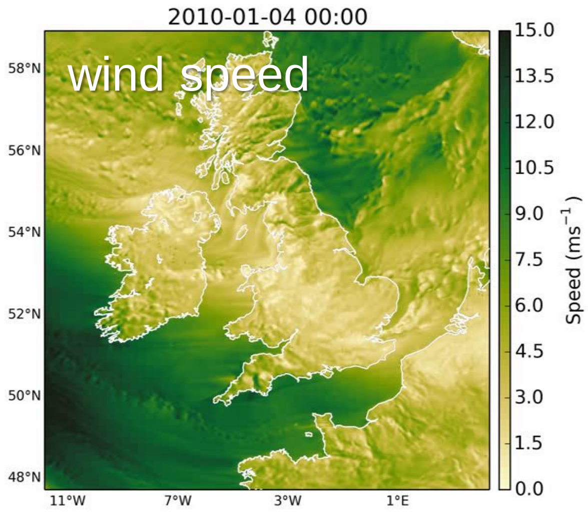
ERSEM

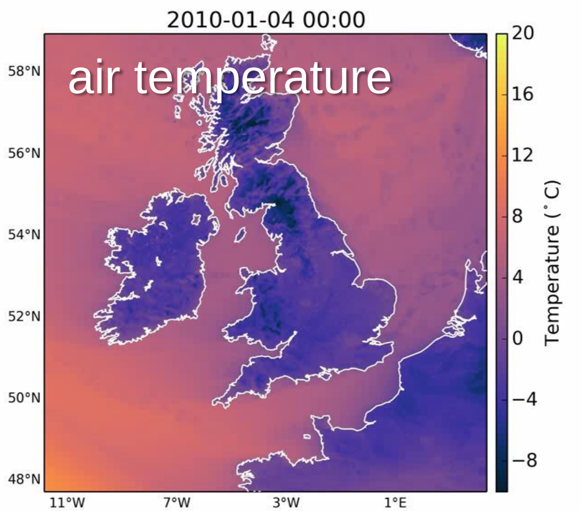
Hydrodynamic modelling: FVCOM

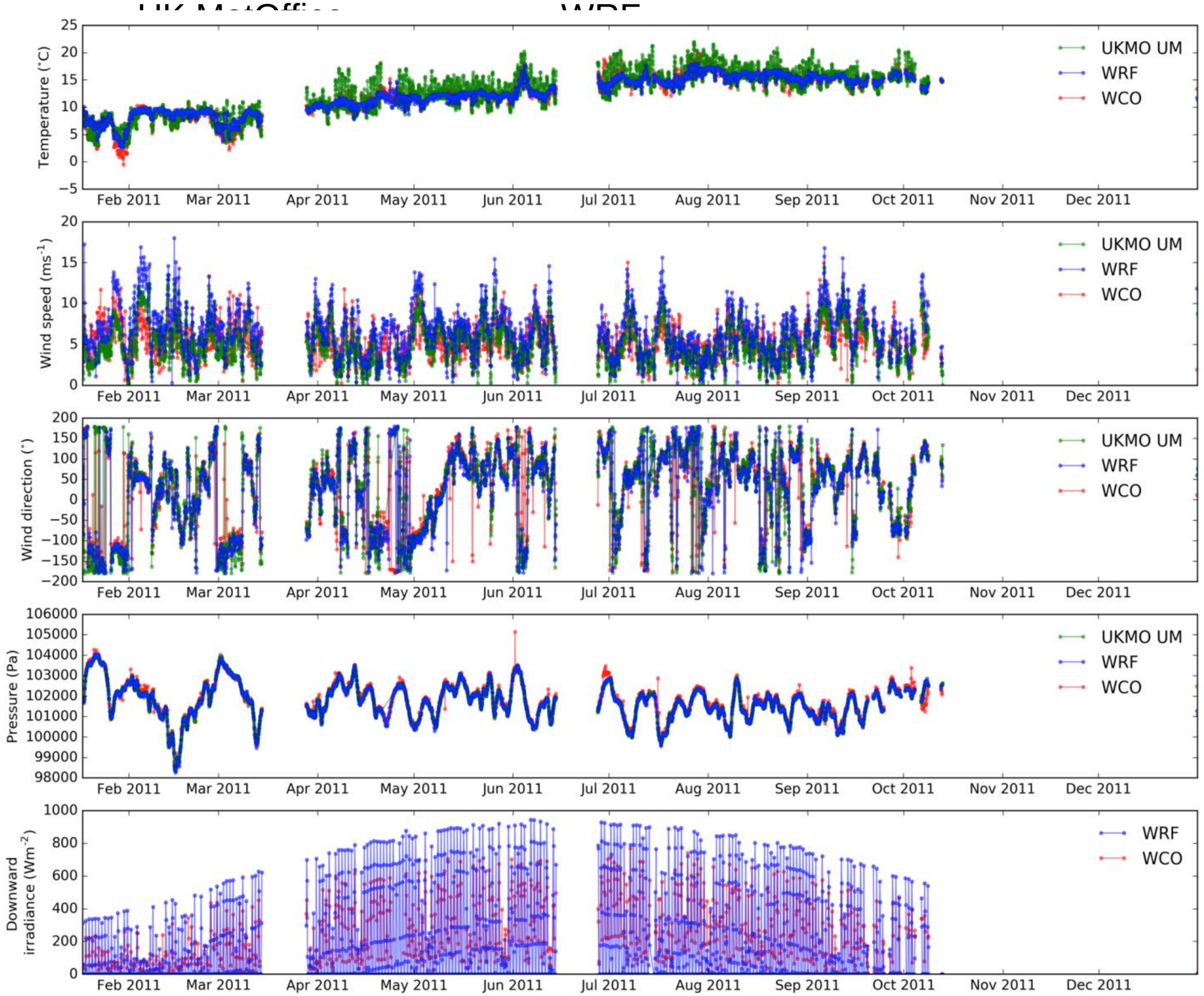
- Finite Volume Community Ocean Model
- **Unstructured:** variable resolution, close fit to complex coastlines
- **High quality forcing:** high resolution atmospheric fields, SST assimilation
- **Nesting:** maximize resolution in key regions
- **Online coupling**
  - ecosystems: FABM-ERSEM
  - sediments: USGS CMCST
- Drives **Lagrangian particle model** (PyLag)
- **Operational** in end 2018



Hydrodynamic modelling: quality meteorology



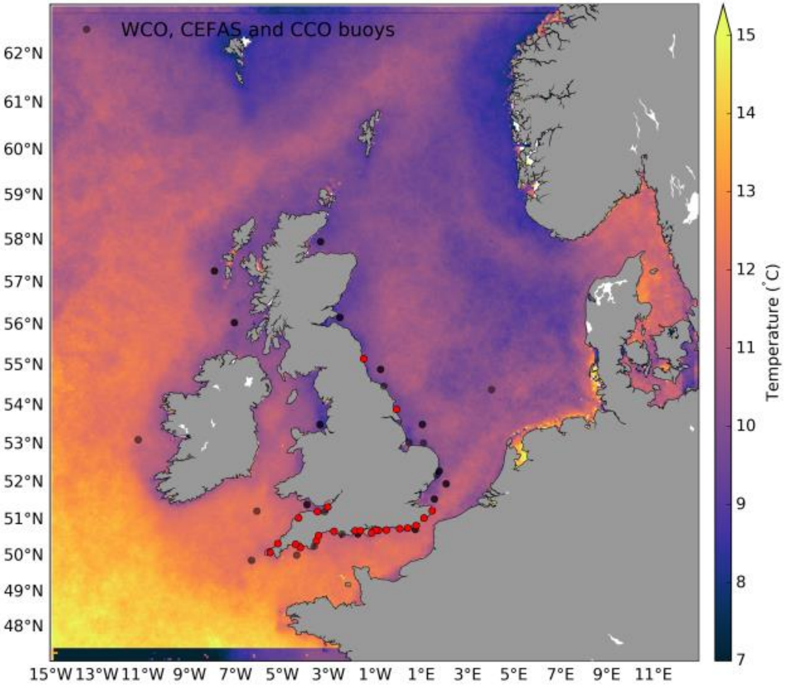


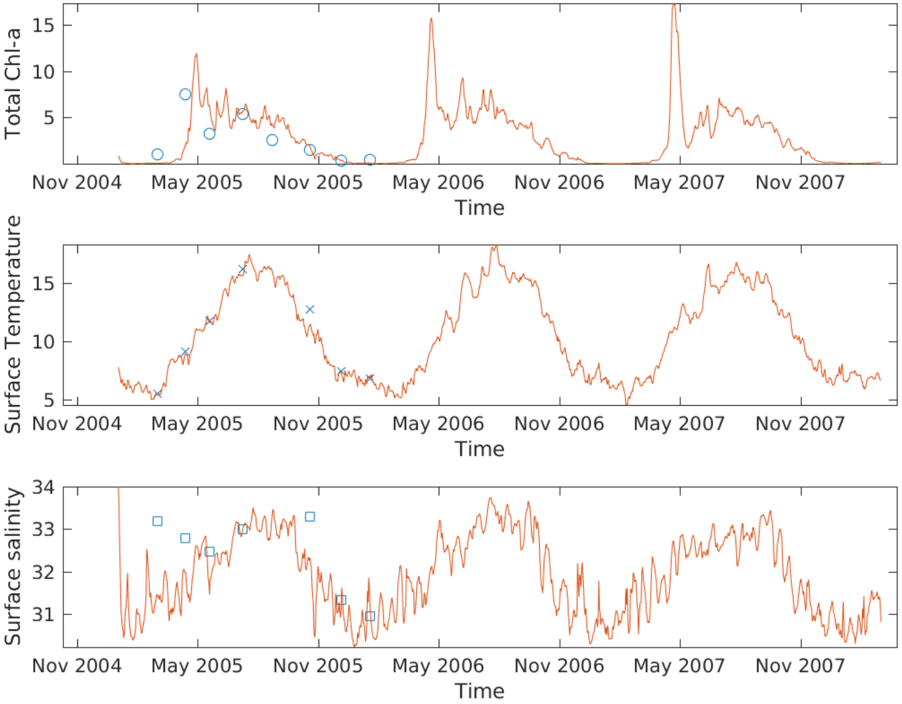


Weather Research and Forecasting Model (WRF); 3 km resolution, three hourly

Hydrodynamic modelling: validation

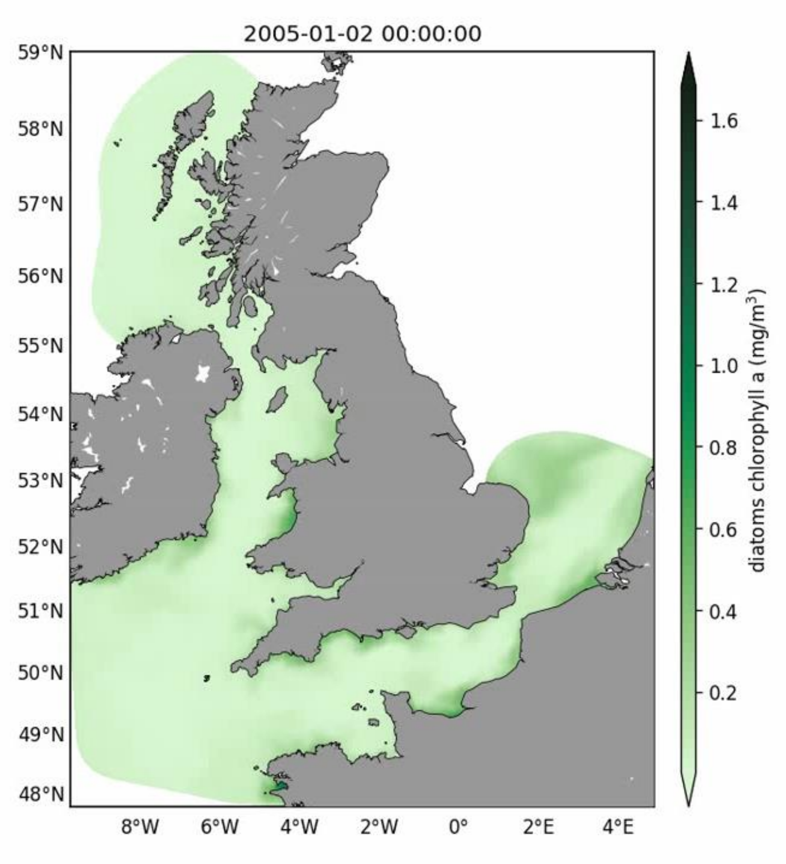
in situ buoys





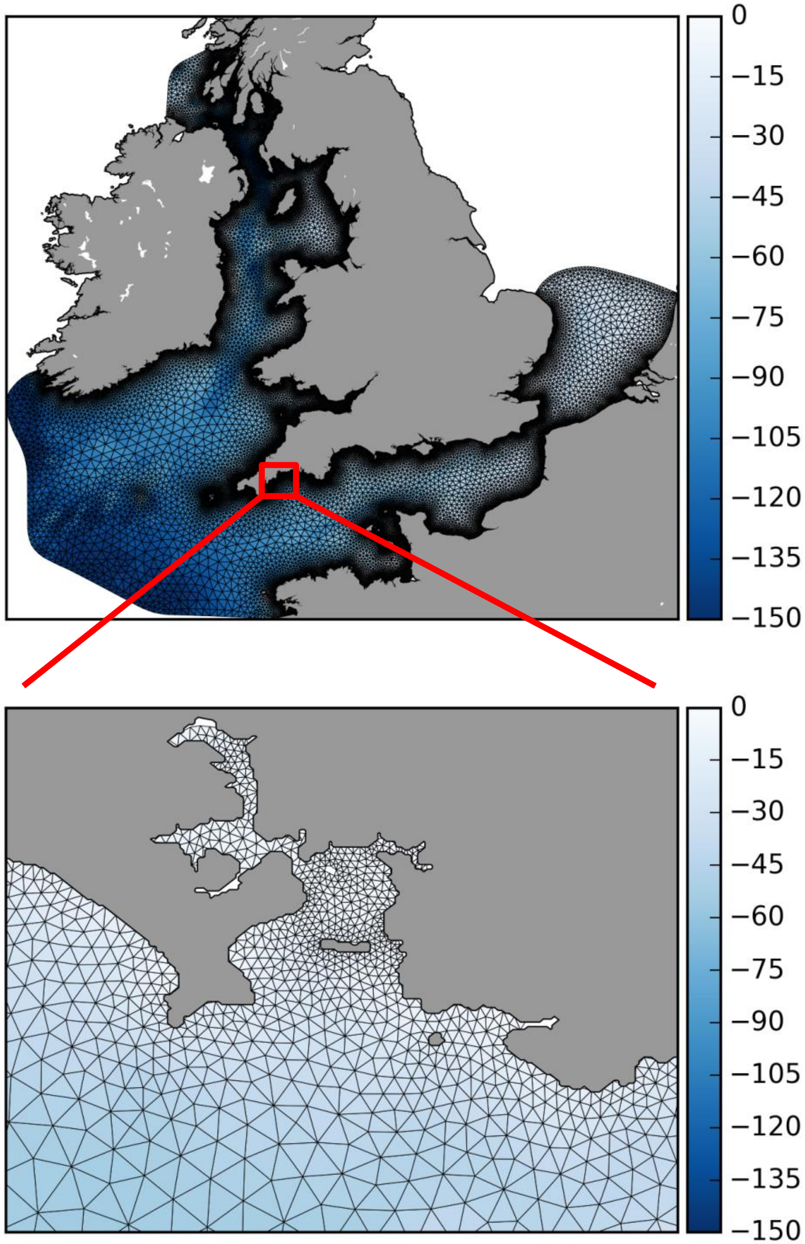
Hydrodynamic modelling: ecosystem coupling

seasonality in surface chlorophyll



Particle tracking: PyLag

- Originally developed to study the transport and fate of **marine microplastic debris** away from known source regions.
- It supports running ensemble simulations in parallel, making it possible to simulate the movement of many millions of particles.
- Includes **direct support for FVCOM** and can be easily extended to accept data on different grids.



Clark *et al* (in prep)

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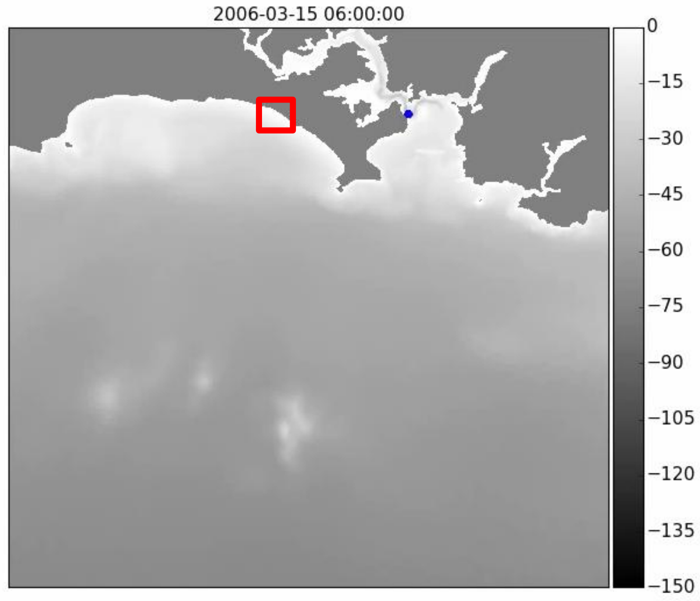
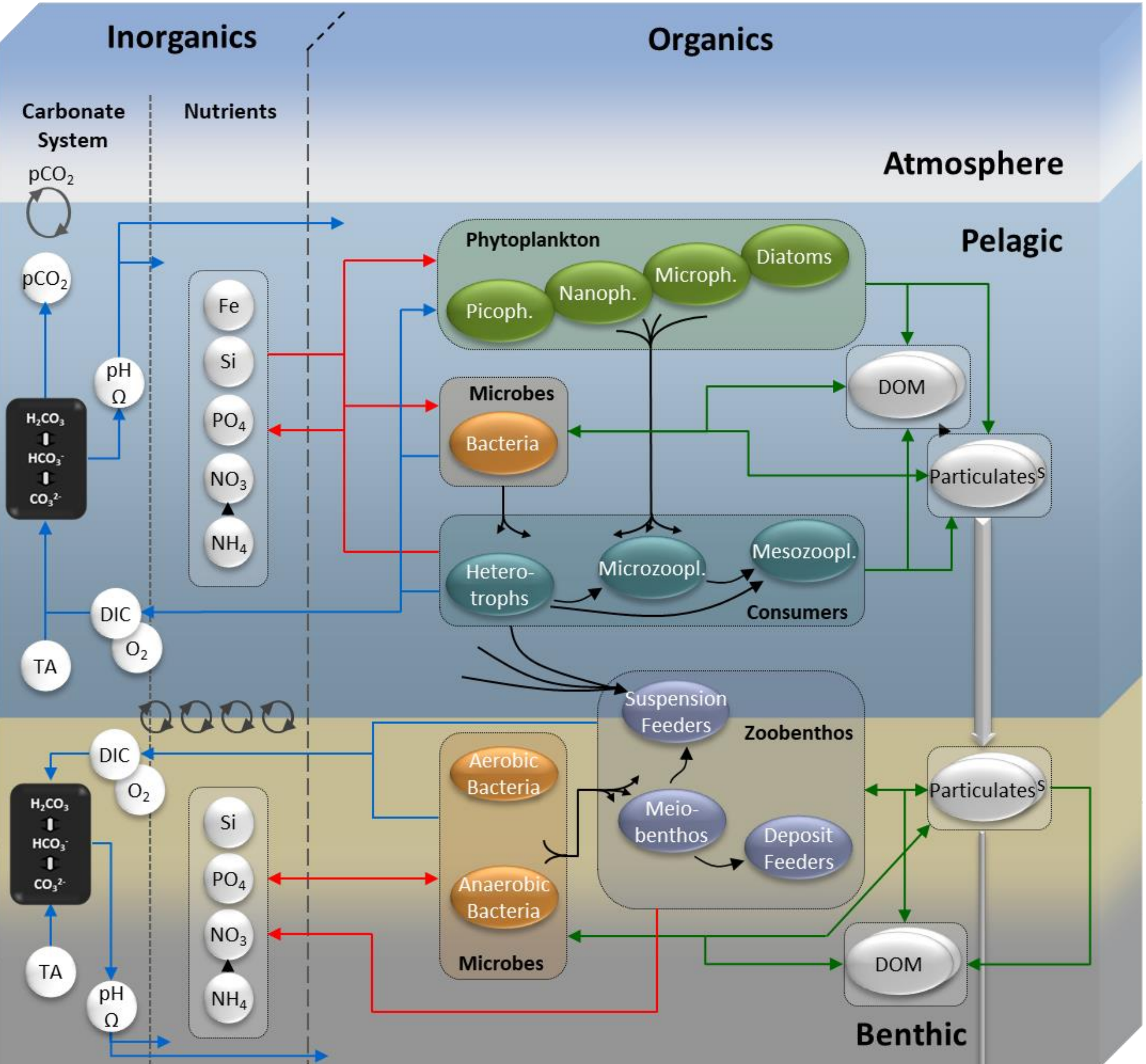
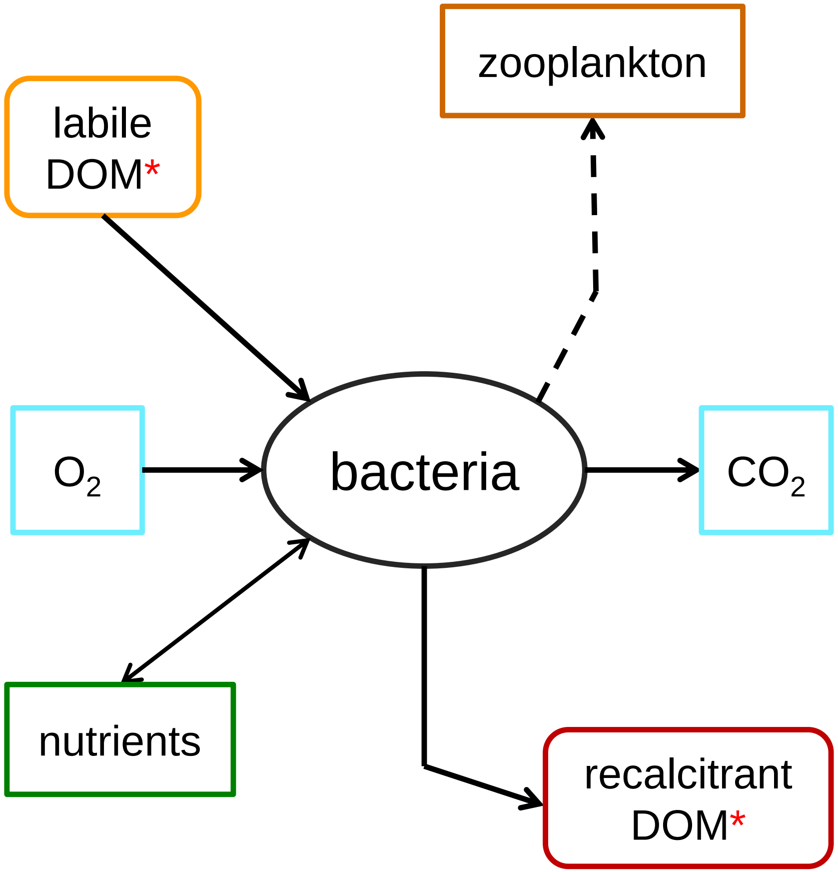


Ecosystem modelling: FABM-ERSEM



features	
4	primary producers • diatoms • picophytoplankton • nanophytoplankton • microphytoplankton
3	zooplankton groups • heterotrophic nanoflagellates • microzooplankton • mesozooplankton
3	benthic fauna groups • meiofauna • suspension feeders • deposit feeders
5	chemical elements C, N, P, Si, Fe

Process modelling: bacteria and organic matter



Bacterial roles:

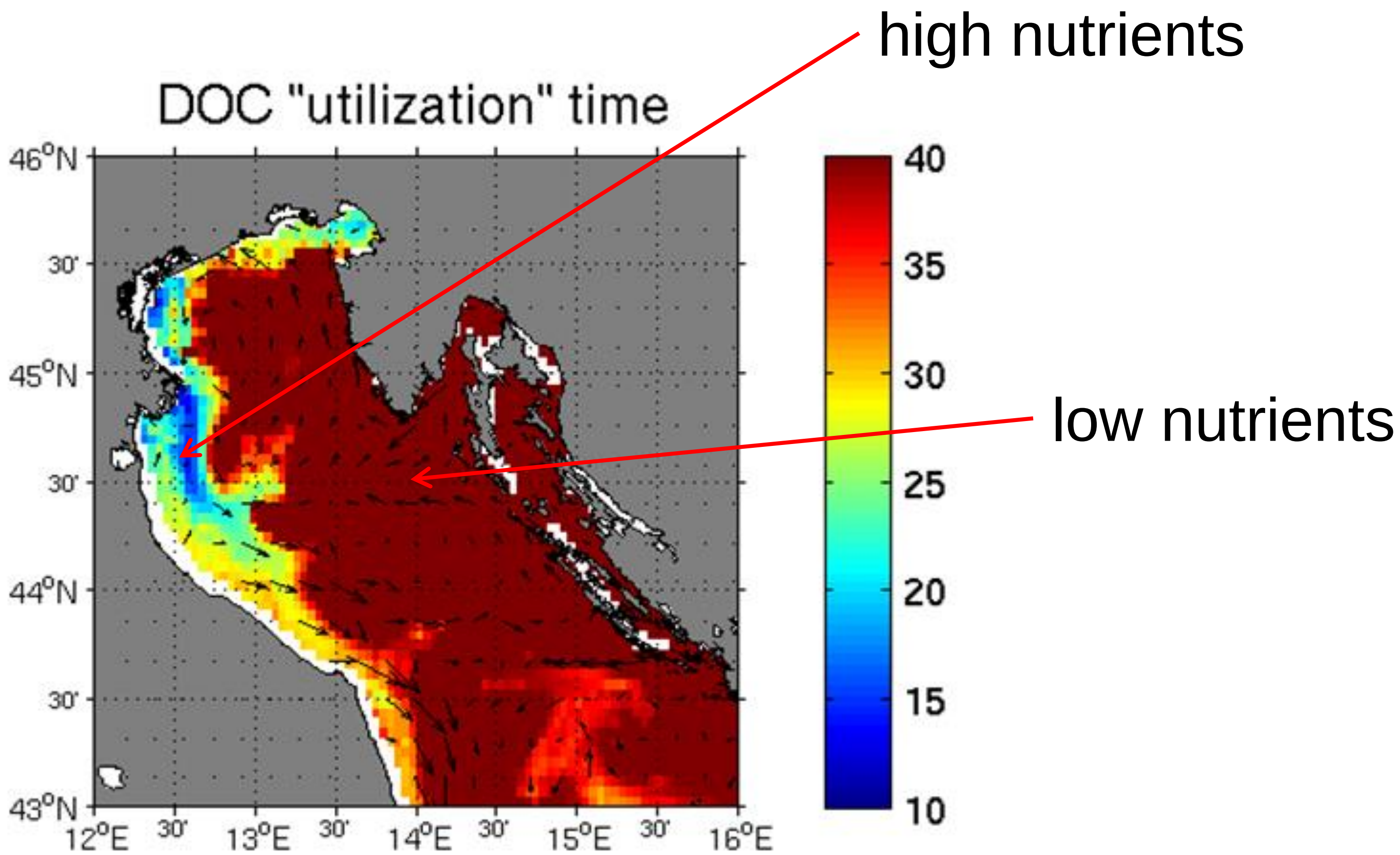
- Conversion of DOM to POM
  food for higher trophic levels
- Nutrient and O_2 use, CO_2 production
  competition with phytoplankton for nutrients
- Production of recalcitrant DOM
  DOM processing

The relative magnitude of these processes is variable

*LDOM, degradation time= ~days (Hansell, 2013)

*RDOM, degradation time= from months to millennia

Example: biodegradation depends on nutrients



Northern Adriatic Sea

Polimene et al., (2007, JGR)

Toward biodegradation of spills: time scales

Most oil spill models have been designed for short-term forecasts. On these time scales, physico-chemical processes dominate.

But the ultimate fate of most of the crude oil that enters the marine environment is biodegradation

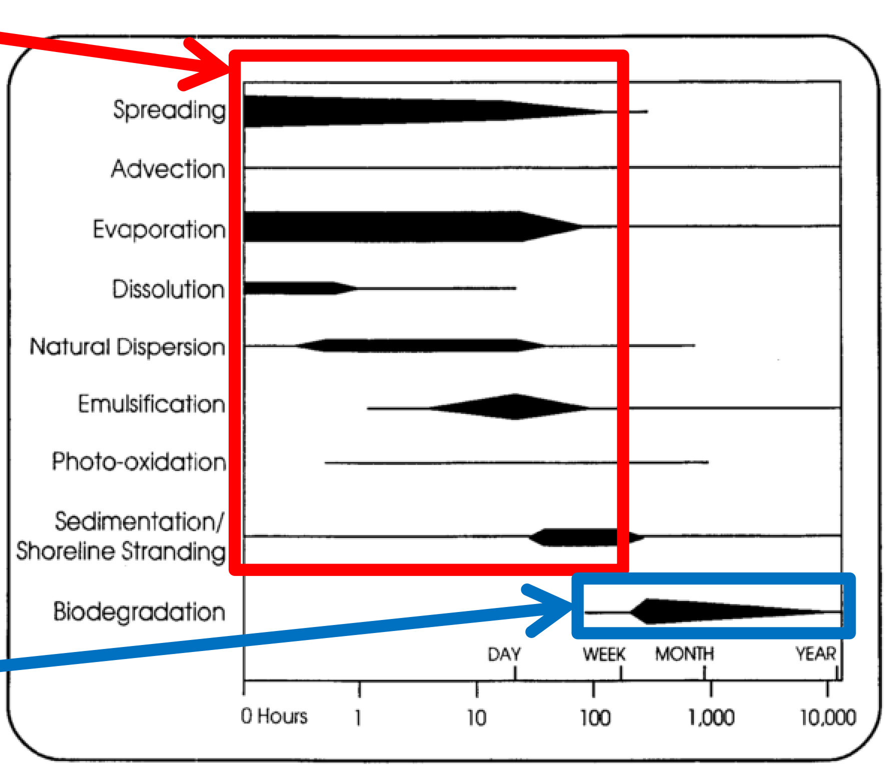


Figure 3. Relative importance of the weathering processes on a "generic" oil slick over time. The width of the line indicates the magnitude of the process relative to other processes. Adapted from Exxon (1985).

Scholz *et al.* (1999) "Fate of spilled oil in marine waters" American Petroleum Institute

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Towards biodegradation of spills: controls

Individual species of microbes degrade specific chemical components

Thus, <u>biodegradation depends on</u>:

- chemical composition of spill
- microbial abundance and community composition
- nutrient availability
- environment: temperature, salinity, pH, pressure

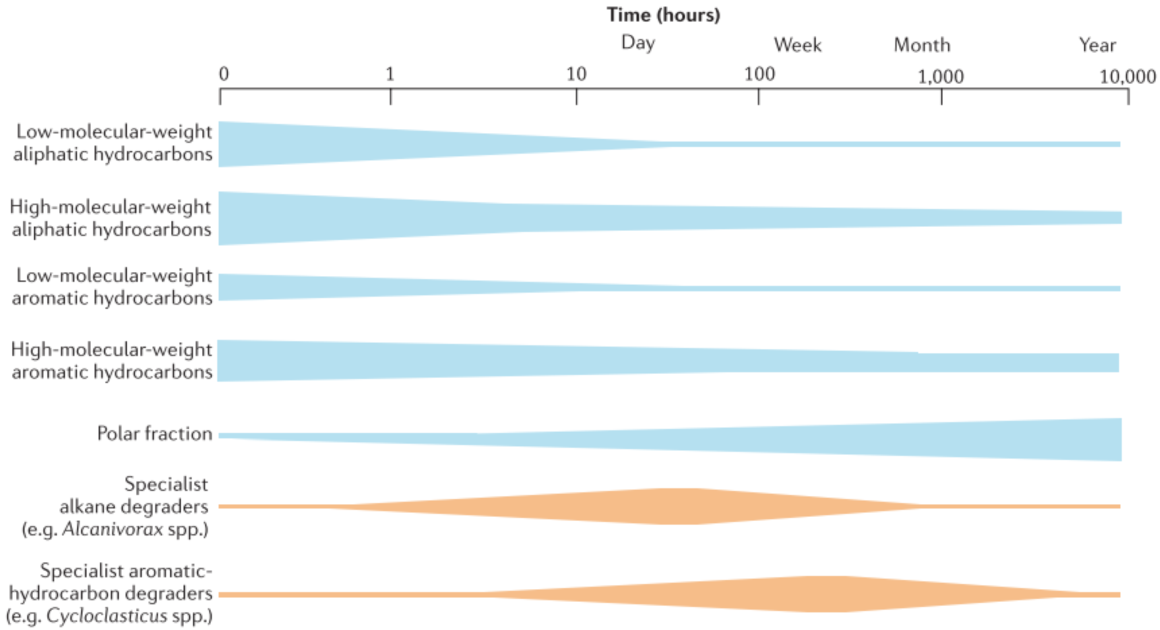


Figure 3 | **Changes in the composition of spilled oil and corresponding changes in the abundance of key organisms.** This schematic diagram represents general changes that have been observed in several studies. Slight variations are likely, both in the specific organisms that are involved and in the extent of biodegradation of different crude oils, which have a range of physical and chemical properties that affect their fate in the environment.

Head, Jones, Röling, Marine microorganisms make a meal of oil. *Nat. Rev. Microbiol.* **4**, 173–82 (2006)

Towards biodegradation of spills: proposal

1. Characterize oil components

identify properties that predict degradation rate, e.g.,:

- molecular weight
- number of aromatic groups
- chemical stability
- enthalpy

2. Make modelled microbes eat oil

link metabolic rate of ERSEM microbes to chemical properties of substrate

3. Evaluate model behaviour

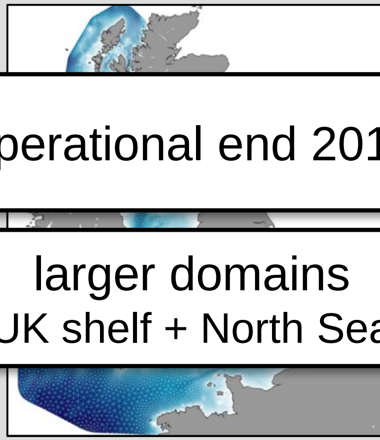
- parameterise against mesocosm studies
- simulate Deepwater Horizon oil spill in water column

4. Add-ons

- embed biodegradation model in spill tracking model
- track fate of oil-derived carbon through ecosystem
- evaluate dispersion-degradation interaction in FVCOM

Future

high resolution hydrodynamics

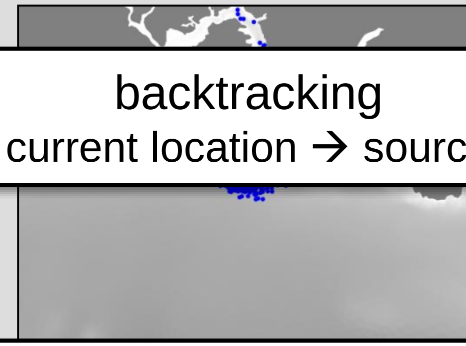


operational end 2018

larger domains
UK shelf + North Sea

FVCOM

particle tracking

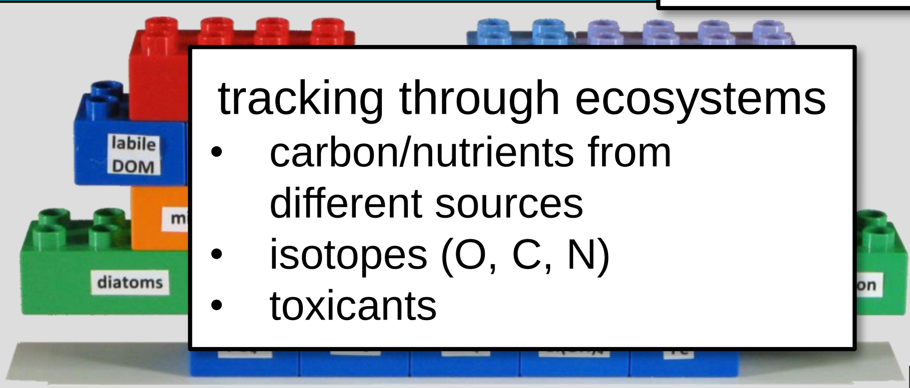


backtracking
current location → source

particles with behaviour
- transport, sinking, & breakup of macroalgae
- dispersal & survival of benthic larvae

PyLag

modular ecosystem



tracking through ecosystems
- carbon/nutrients from different sources
- isotopes (O, C, N)
- toxicants

ERSEM

Thank you