

PML

Plymouth Marine
Laboratory

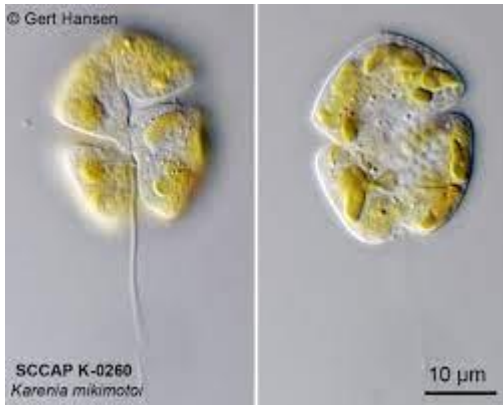
Listen to the ocean

Tracking harmful algae blooms in the western English Channel using digital twins

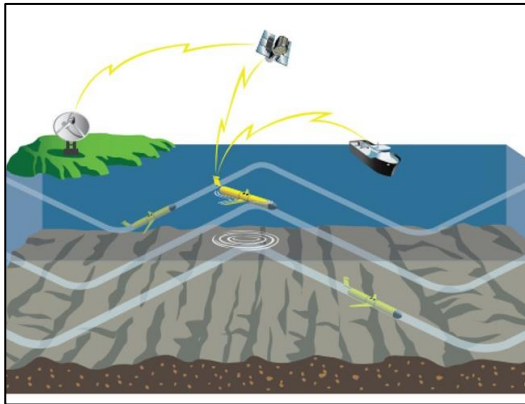
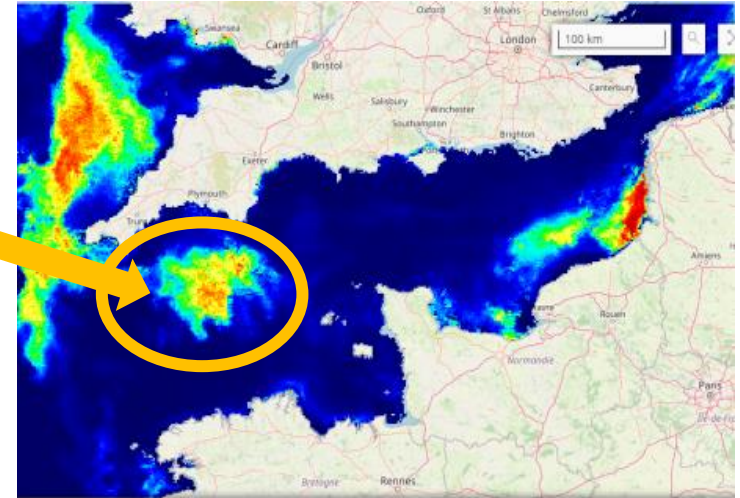
Jozef Skakala (PML, NCEO), Matthew Palmer (PML), Juliane Wihsgott (PML), Prathyush P Menon, Ke Wang (University of Exeter), Tom Mansfield (PML), Dale Partridge (PML, NCEO), Susan Kay (PML, Met Office), David Ford (Met Office), Gavin Tilstone (PML), Dan Clewley (PML), Deep Banerjee (PML, NCEO) and others...



Scientific challenge: monitor and understand better the drivers, dynamics and consequences of harmful blooms happening in the English Channel

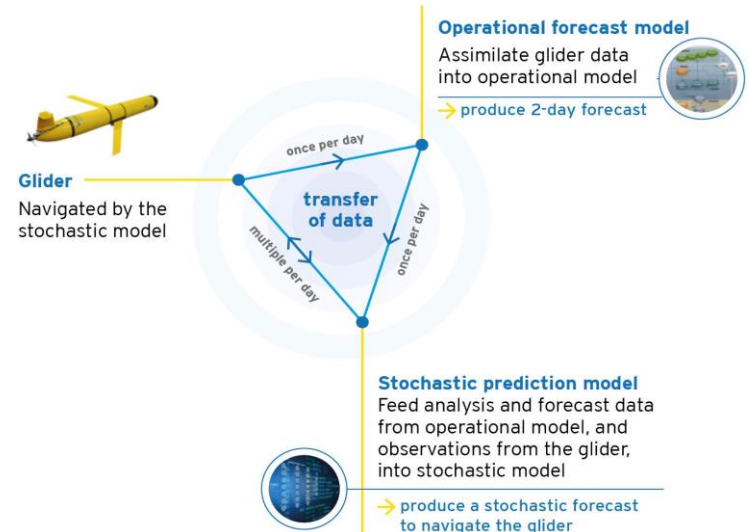


Karenia Mikimotoi bloom



Digital twin systems

Observing mission using AUVs (gliders), could provide us with essential observations in high resolution and 3D. The idea is to navigate the AUVs with a digital twin system.





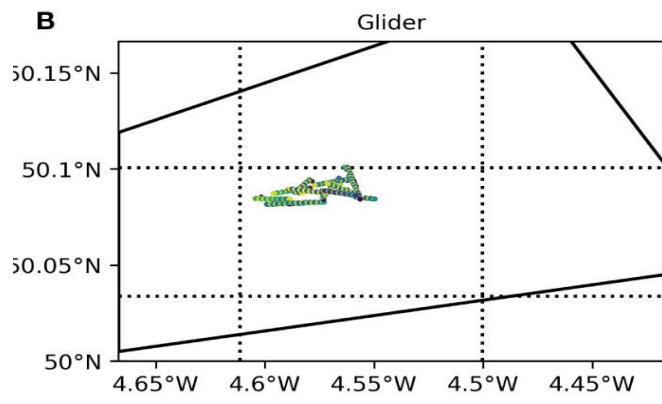
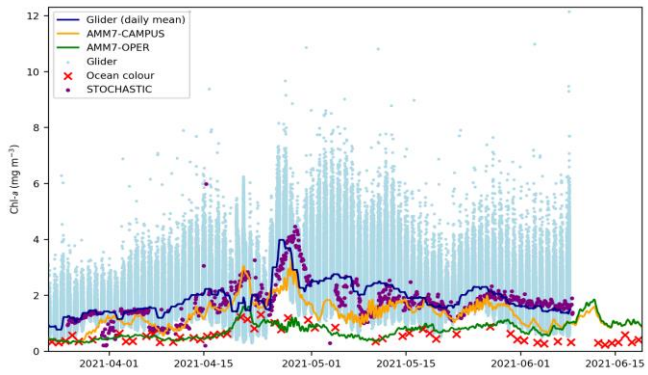
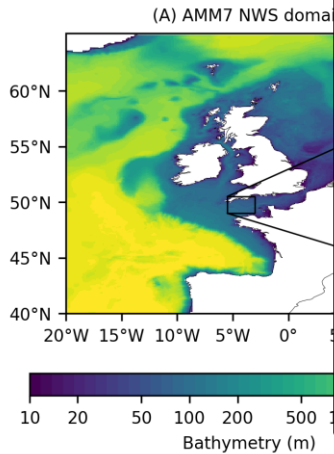
In 2022 we developed a first example of fully autonomous “smart” observing system detecting the onset of phytoplankton bloom

We developed a successful digital twin, with glider navigated by a combined operational and stochastic forecasts, reinitialized by the glider observations

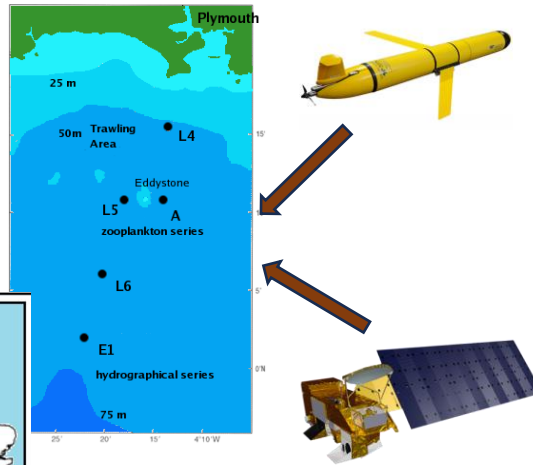
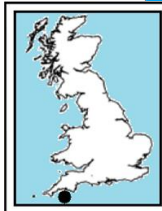
Ford et al (2022) paper, *Frontiers in Marine Science*

Some issues:

- there were visible biases among different data-sources, e.g. satellite OC product and glider fluorescence measurements,
- operational model had very coarse resolution relative to the glider scale,
- what to do with 1 glider if we want to follow multiple goals?



- **Intercalibration of satellite and glider with “gold”-standard WCO data**



- **Move to higher resolution: from AMM7 (7km) down to AMM15 (1.5km). Required first time seriously testing MBGc in AMM15 and also NEMOVAR BGC DA in AMM15!**

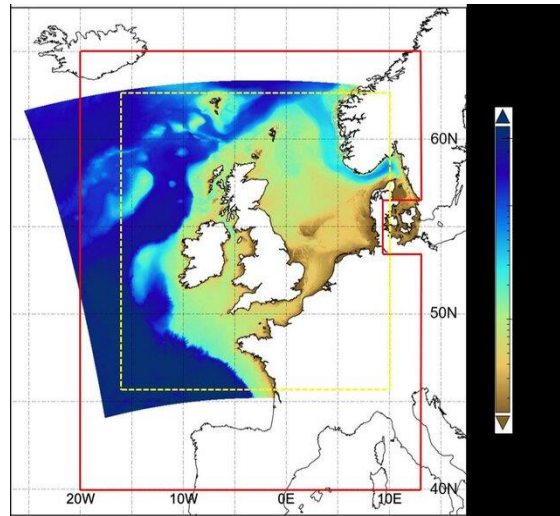
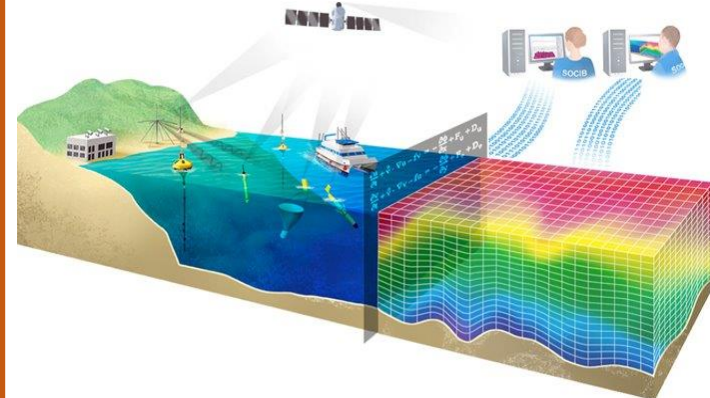


Figure taken from Tonani et al, 2019

Run three gliders, each given different task: 1-2 focus on chlorophyll features and the third tracks the oxygen minima.. This requires path planning to coordinate the vehicles



Details of the mission:

Observations (assimilated):

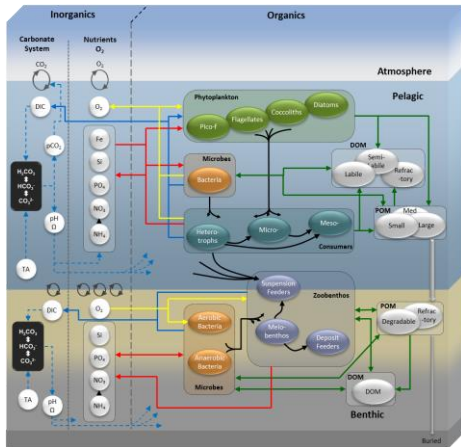
- EO – SST (2xday) and OC total chlorophyll (1xday)
- Hadley data for T & S
- Glider full depth profiles for T, S, chl and O₂ (4xday)

Observations (calibration):

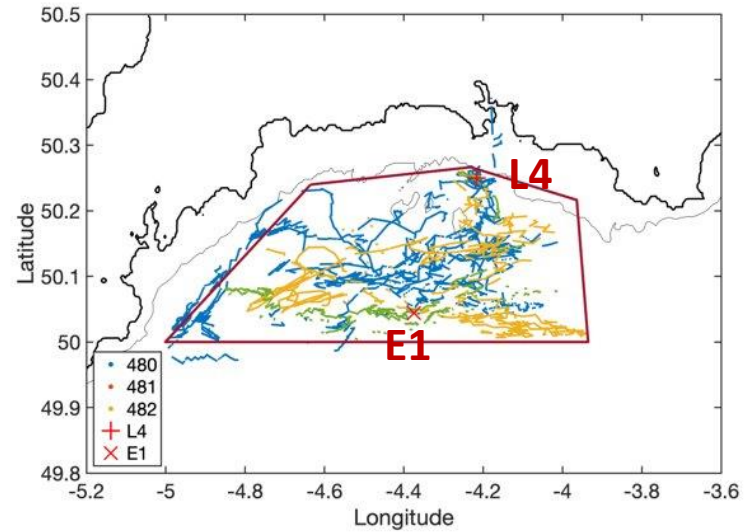
- WCO (L4, E1): weekly full profiles of T, S, Chl, O₂ and hourly SST

AMM15 NEMO-FABM-ERSEM + NEMOVAR

- daily assimilation and 3-day forecast

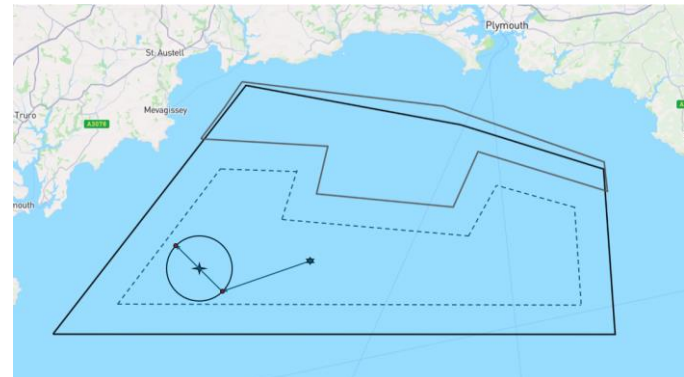


06/08/2024 – 29/09/2024

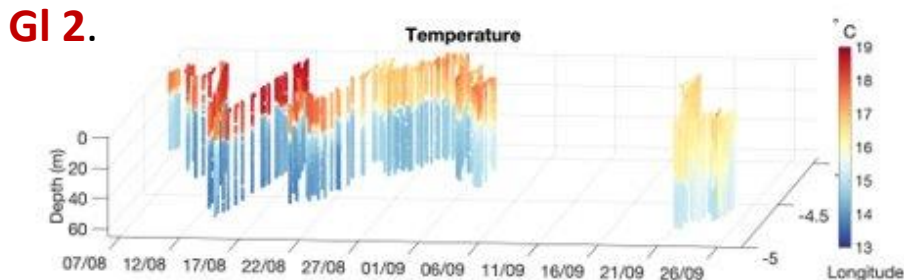
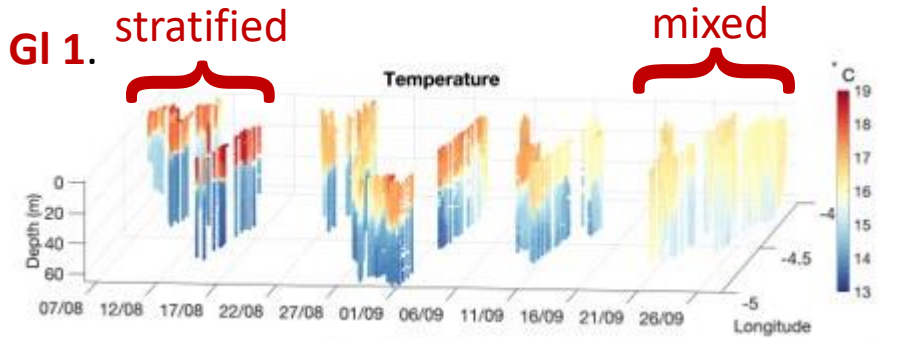
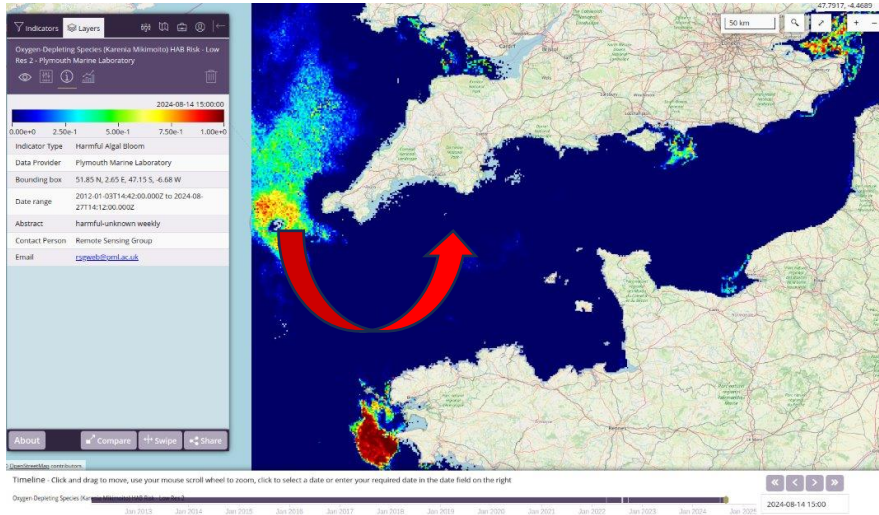


PATH PLANNING

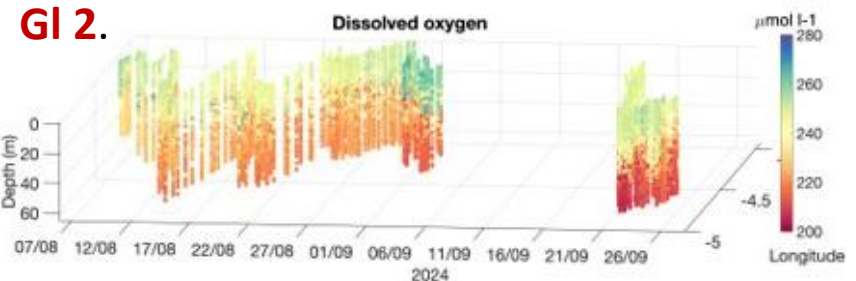
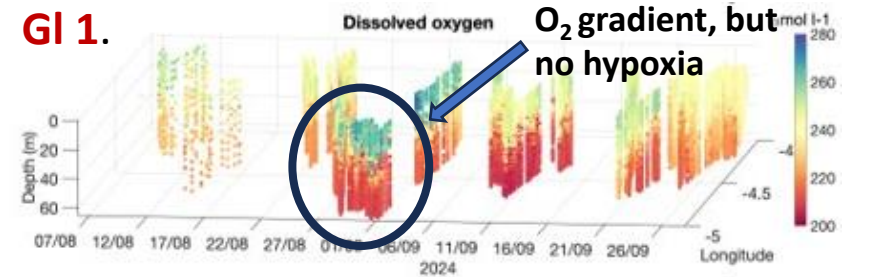
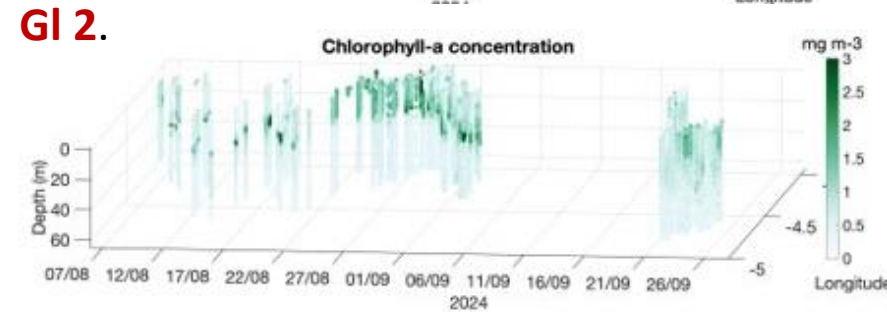
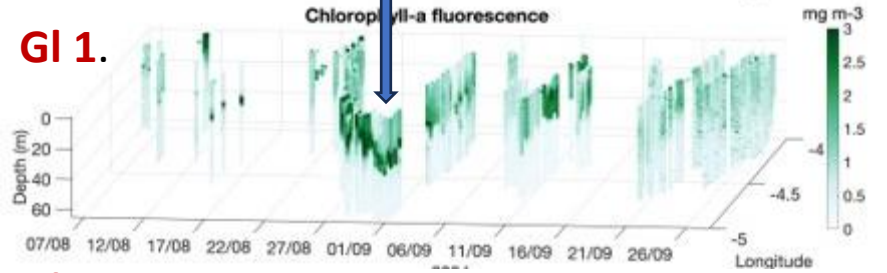
- Using Gaussian Process model and analysis + forecast data and calculating waypoints every day to navigate the glider



Late July – early August: Karenia HAB was moving in the right direction!

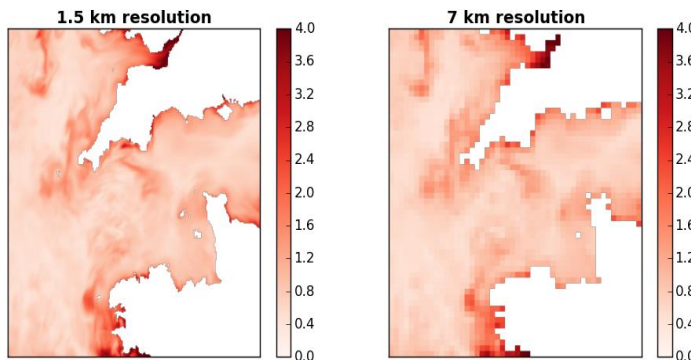


It is still inconclusive whether we crossed our paths with Karenia..

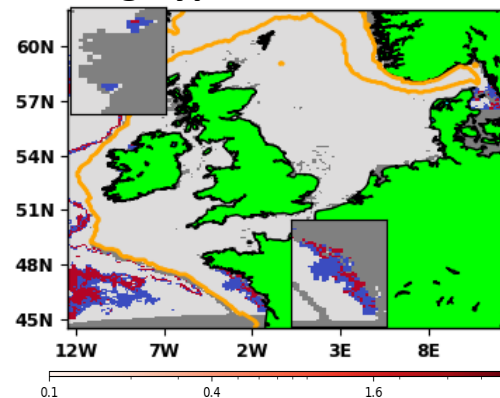


The AMM15 model

The impact of higher resolution



Missing hypoxia events at 7km



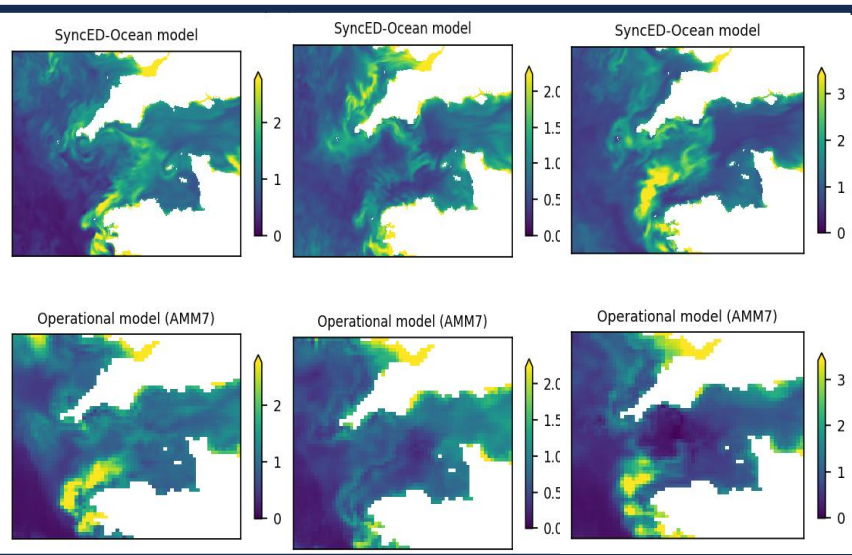
Operational model difference AMM7 vs AMM15

Surf chlorophyll

31/08

10/09

17/09



AMM15

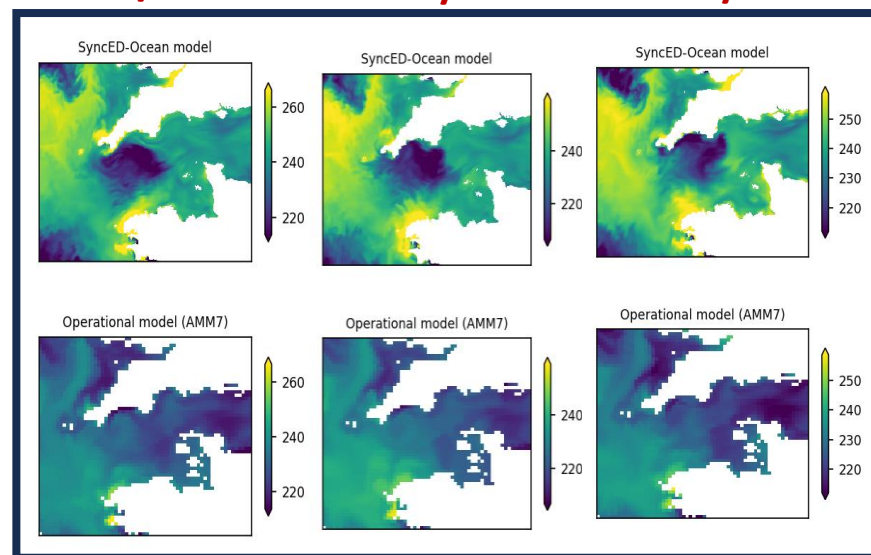
AMM7

Bottom oxygen

31/08

10/09

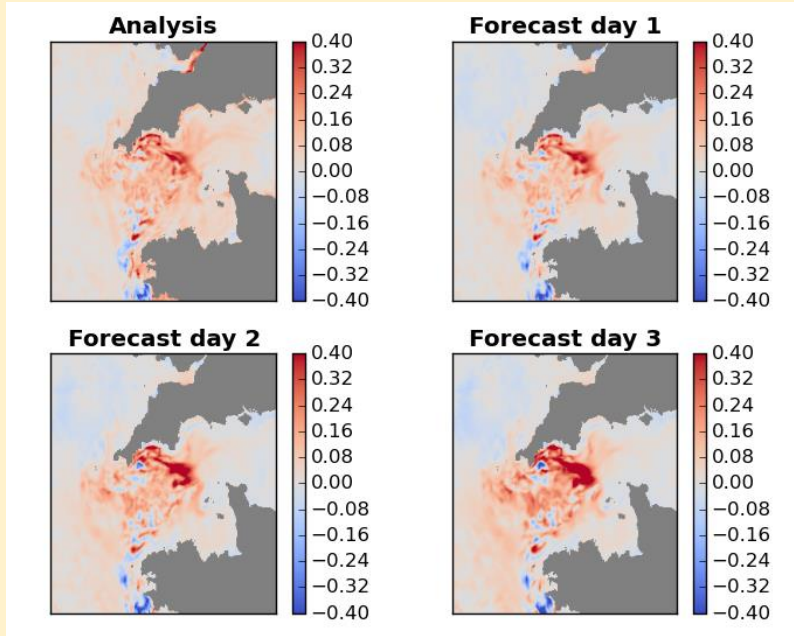
17/09



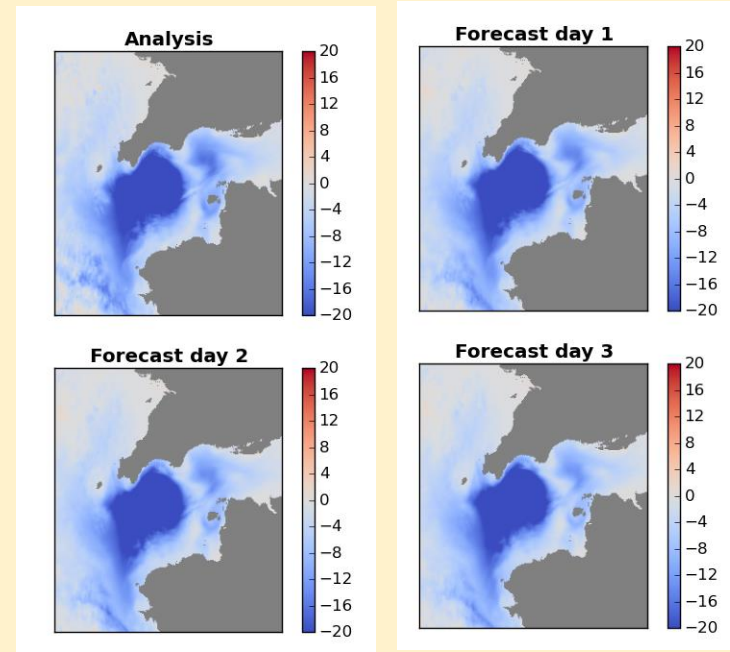
AMM15

AMM7

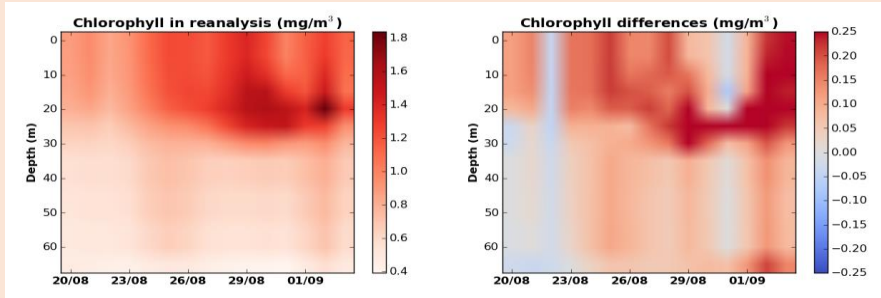
Surf chlorophyll (period 20/08-03/09):



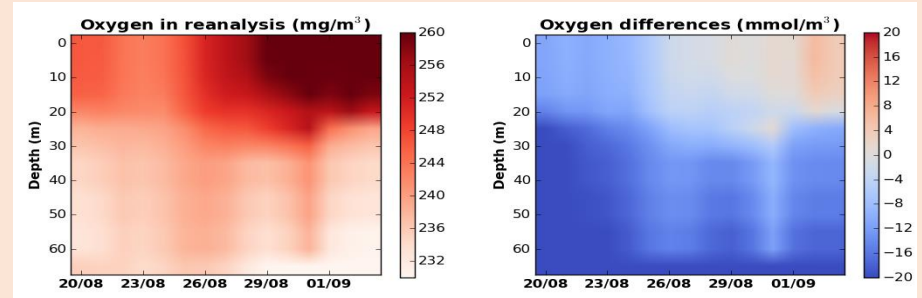
O₂ at 35m depth (period 20/08-03/09):



Chlorophyll



Oxygen



- *Successful DT demonstrator for HAB tracking mission*
- *Gliders provide a priceless high-resolution 3D view of multiple essential ocean variables, but more thought needs to be on technological design as there were several important glider issues during the mission*
- *It is essential to cross-calibrate data sources during the mission, but this can also become a logistical nightmare*
- *The 1.5 km model so j [redacted] nce, but it is extremely costly to run – future option*
- *Using multiple gliders [redacted] efit, but a lot of thought needs to go to path-planning algorithms as the tasks becomes increasingly complex*
- *It would be desirable to have better understanding of observational and forecast uncertainties including spatial scales of representativity*
- *Can we develop DT not just with adaptive observations, but also adaptive models?*
- *New technologies and components can be added to the DT, e.g. for HABs we could benefit from including plankton imagery cameras*