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Impact of waves on phytoplankton activity: insights from observations and km-scale coupled models

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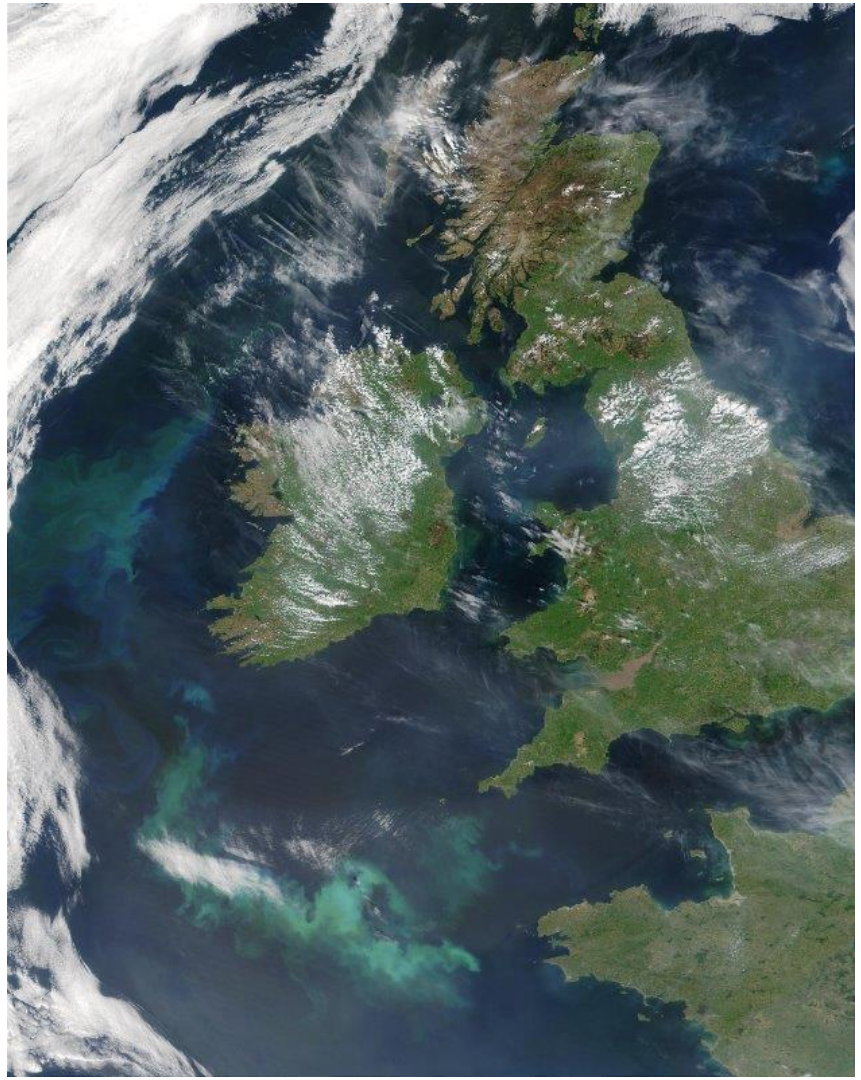
Met Office

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Introduction

- Phytoplankton is a vital part of the marine food web
- Growth is largely dependent on nutrient and light availability – typically blooms occur in spring, with additional events over summer/autumn
- Challenging to predict timing and strength - sensitive to multiple factors
- The NWES contains areas that are permanently mixed and seasonally stratified provided a range of conditions



Questions

- What is the impact of waves on biogeochemistry?
- What is the impact of high wave activity events (storms) on phytoplankton activity?

Waves v Observations

- Correlations between wave energy (modelled) and chlorophyll (satellite) can be significant
- Around the spring bloom period (march-may) a negative off-shelf correlation suggest:
  high wave activity ->
  reduced surface chlorophyll
- Reverse is largely true in the summer period

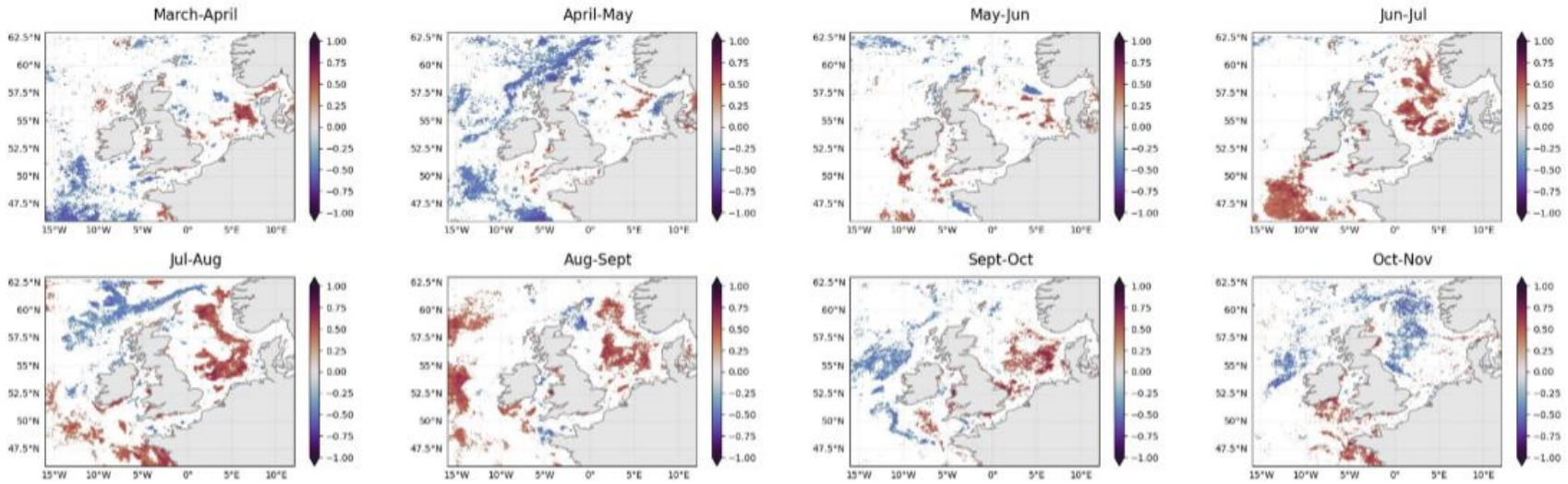


Figure 1: Correlation between monthly-mean wave energy and chlorophyll-a concentration for different pairs of months from 1975 to 2022. Only regions where correlation is significant ($p<0.1$) are coloured.

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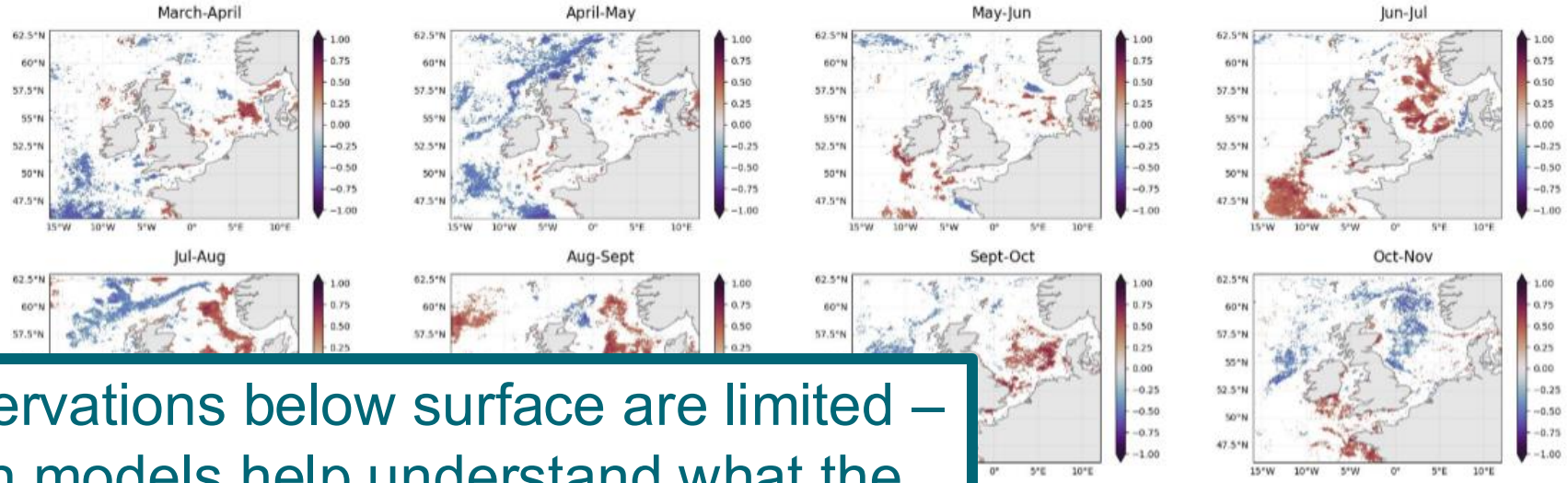

Observations below surface are limited – can models help understand what the effect of wave activity is?

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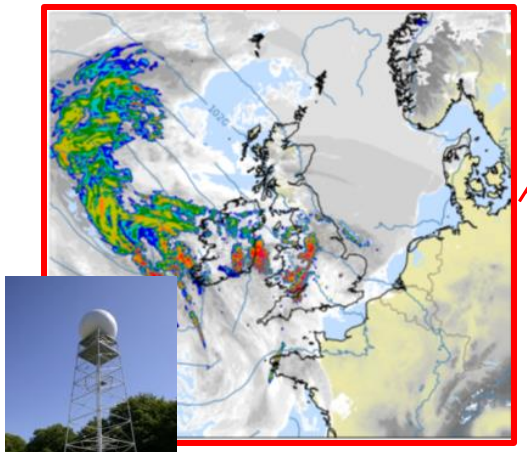
Regional Environmental Prediction Coupled Suite

ATMOSPHERE: UM



Neutral Wind

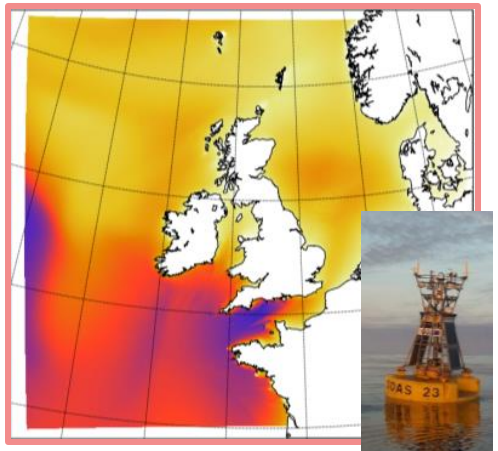
Charnock coefficient

OASIS coupler

Wind, Pressure, Temperature, Radiation, Surface fluxes

SST, Currents

WAVES: WaveWatch III

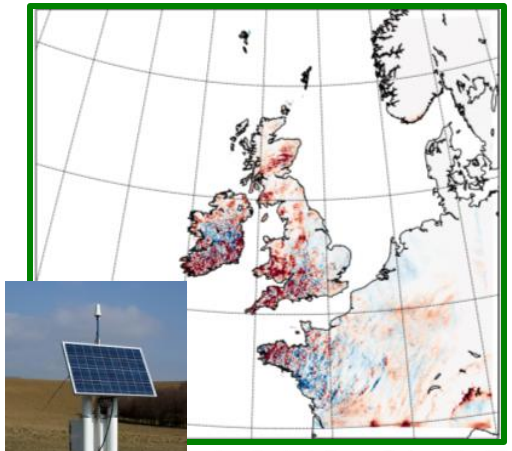


Wave height, Sfc stress

Currents, Depth

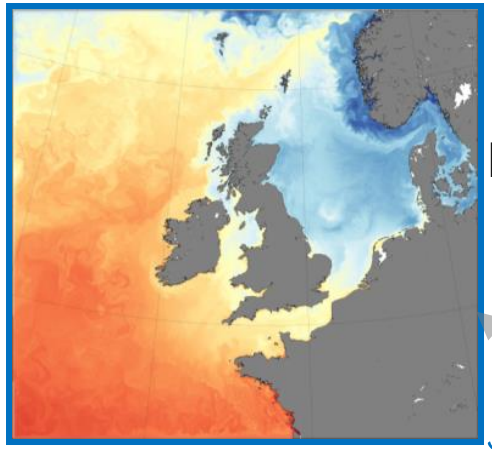
Surface fluxes

Radiation, Temp, Precip, Evap



Inundation

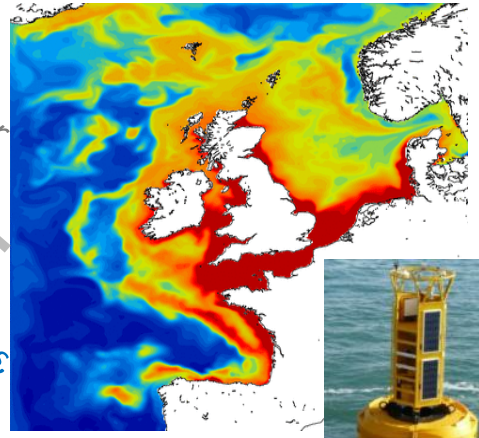
Freshwater



FABM cpl

Water Colour

3D Currents, 3D T, S



River Nutrients, Temperature

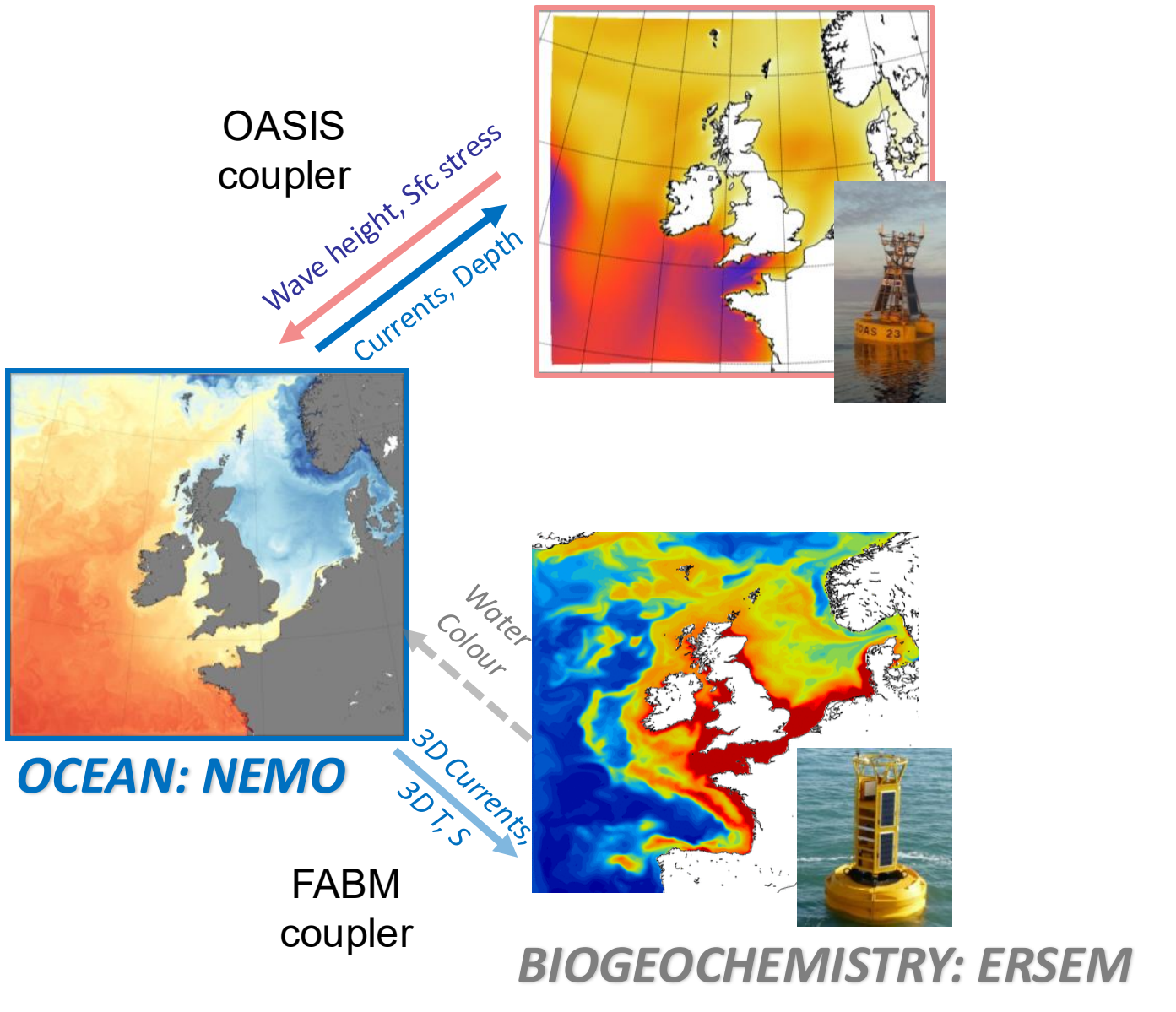
OCEAN: NEMO

LAND SURFACE: JULES

BIOGEOCHEMISTRY: ERSEM

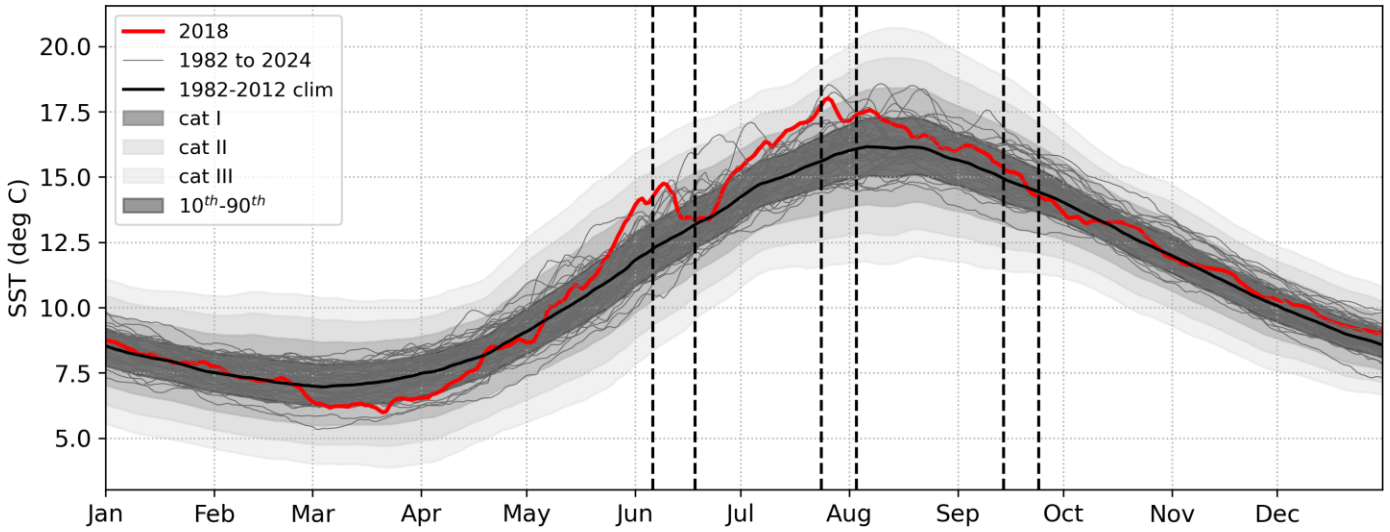
- First time running coupled ocean-wave-bgc
- Two way coupling between ocean and waves
- One way coupling between ocean and bgc
- 1.5km resolution
- Twin experiment over 2018 – one run with waves, ones without

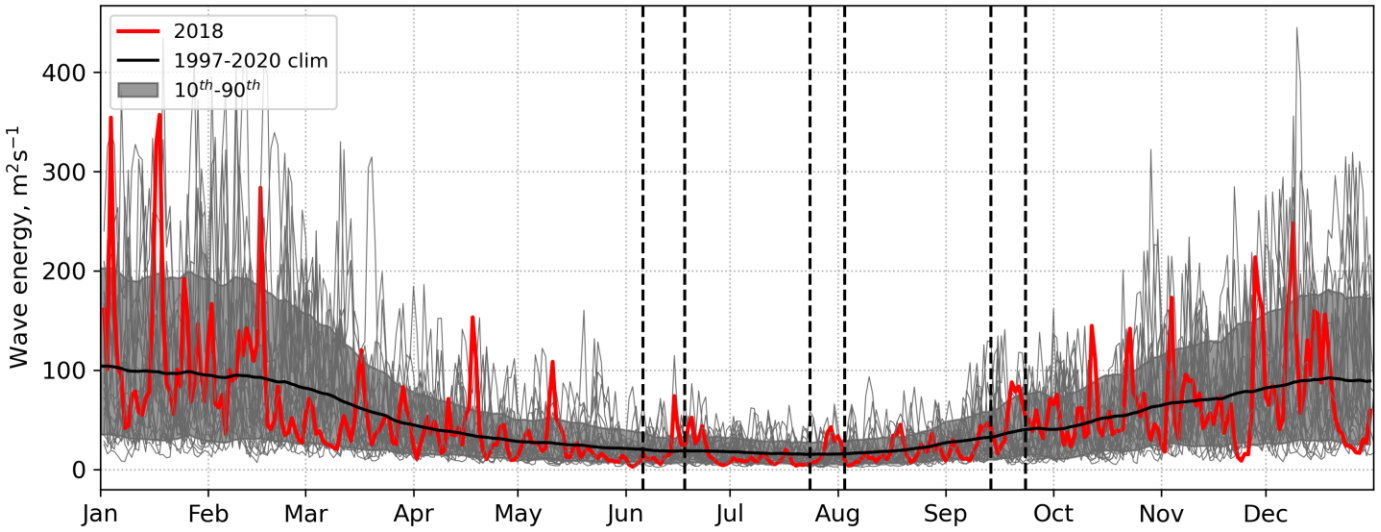
Regional Environmental Prediction Coupled Suite



Why 2018?

- 2018 selected for study due to many interesting features:
  - Cooler surface during March-April with enhanced wave activity
  - Marine heatwaves later in the year (May-June, July)
  - Notable storms
    - Hector (13-14th June)
    - Unnamed (29th July)
    - Ali/Bronagh (18-21 September)





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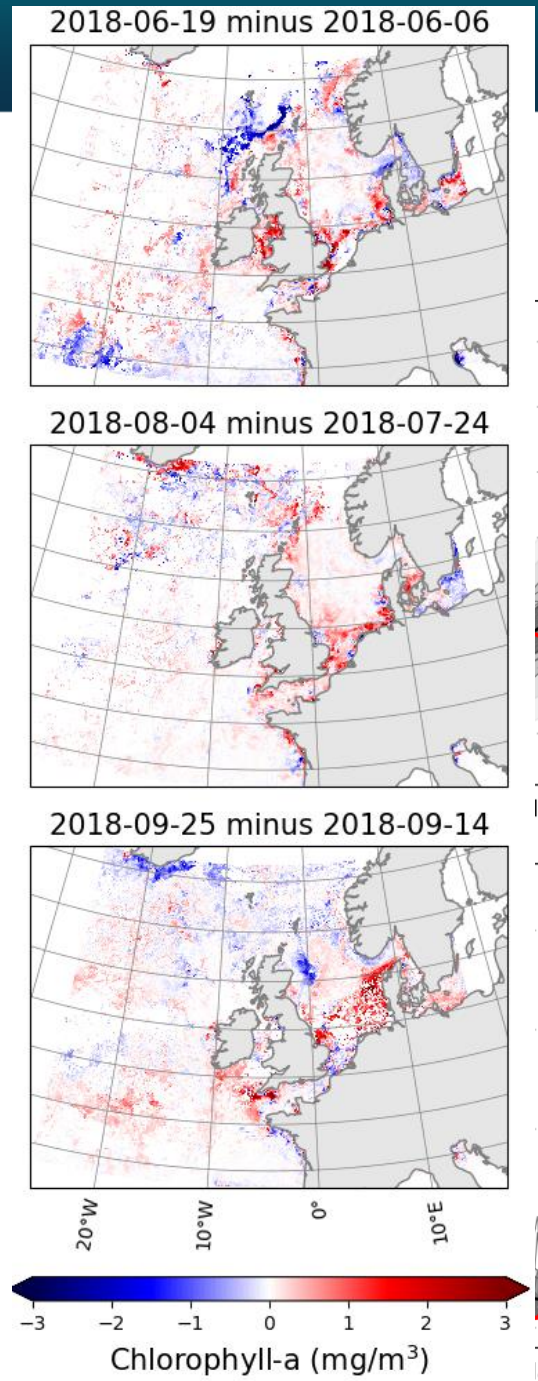
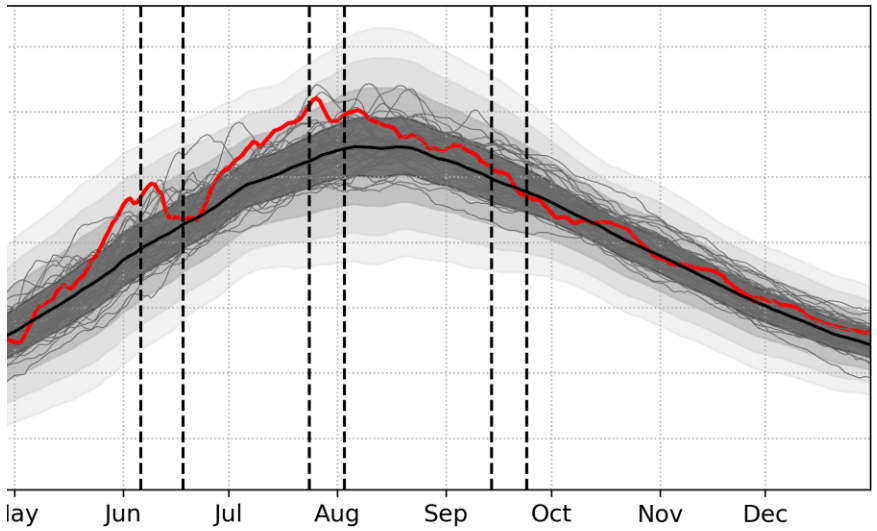
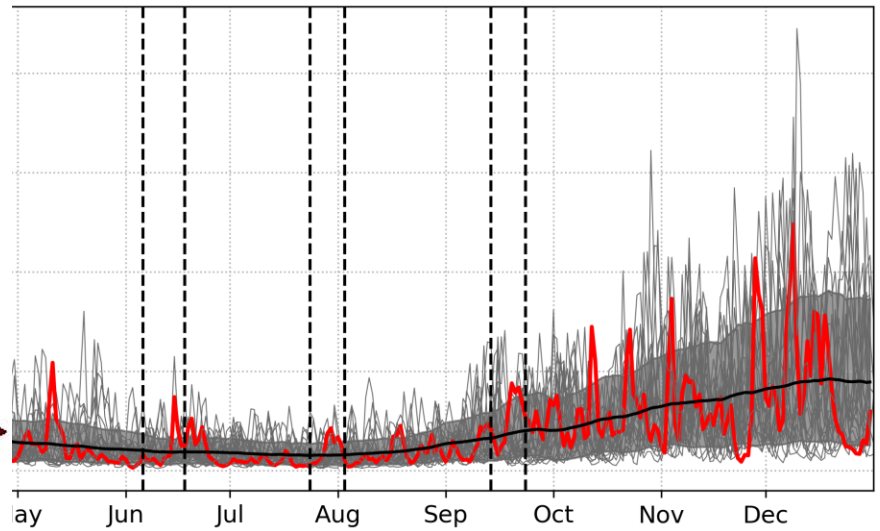
  - Storms can both suppress and enhance phytoplankton activity depending on timing

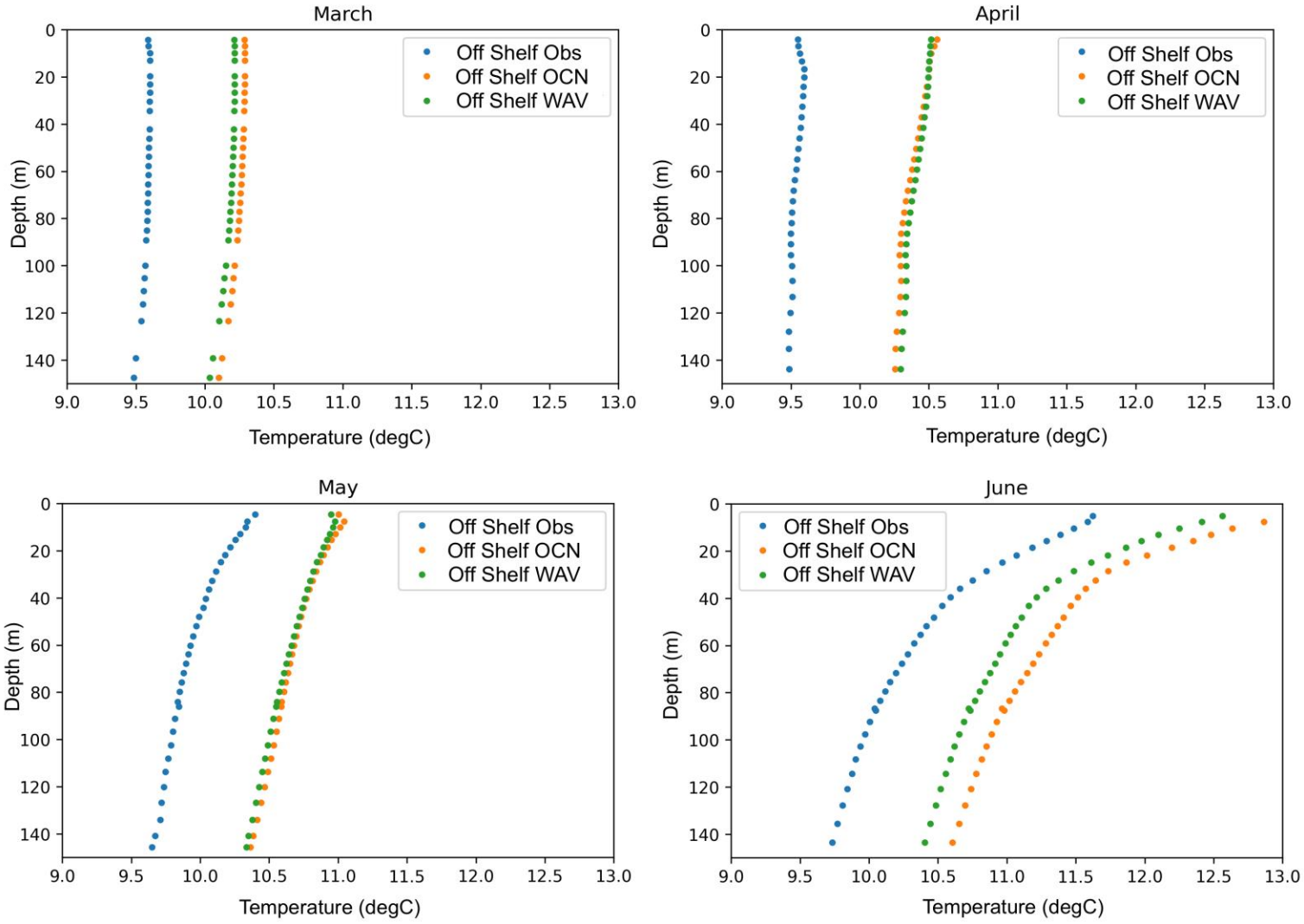






Model Bias

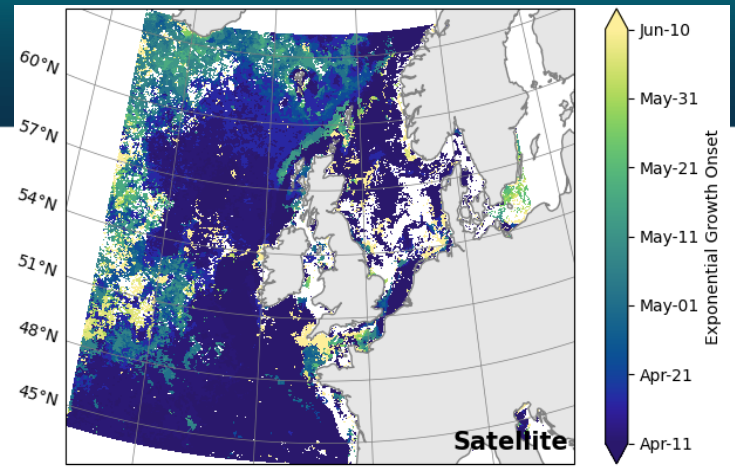
- Comparison of temperature against EN4 profiles
- Persistent warm bias off-shelf
- Minimal improvement with waves in spring when water column is well mixed
- In stratification season the impact of waves is greater and the bias is reduced

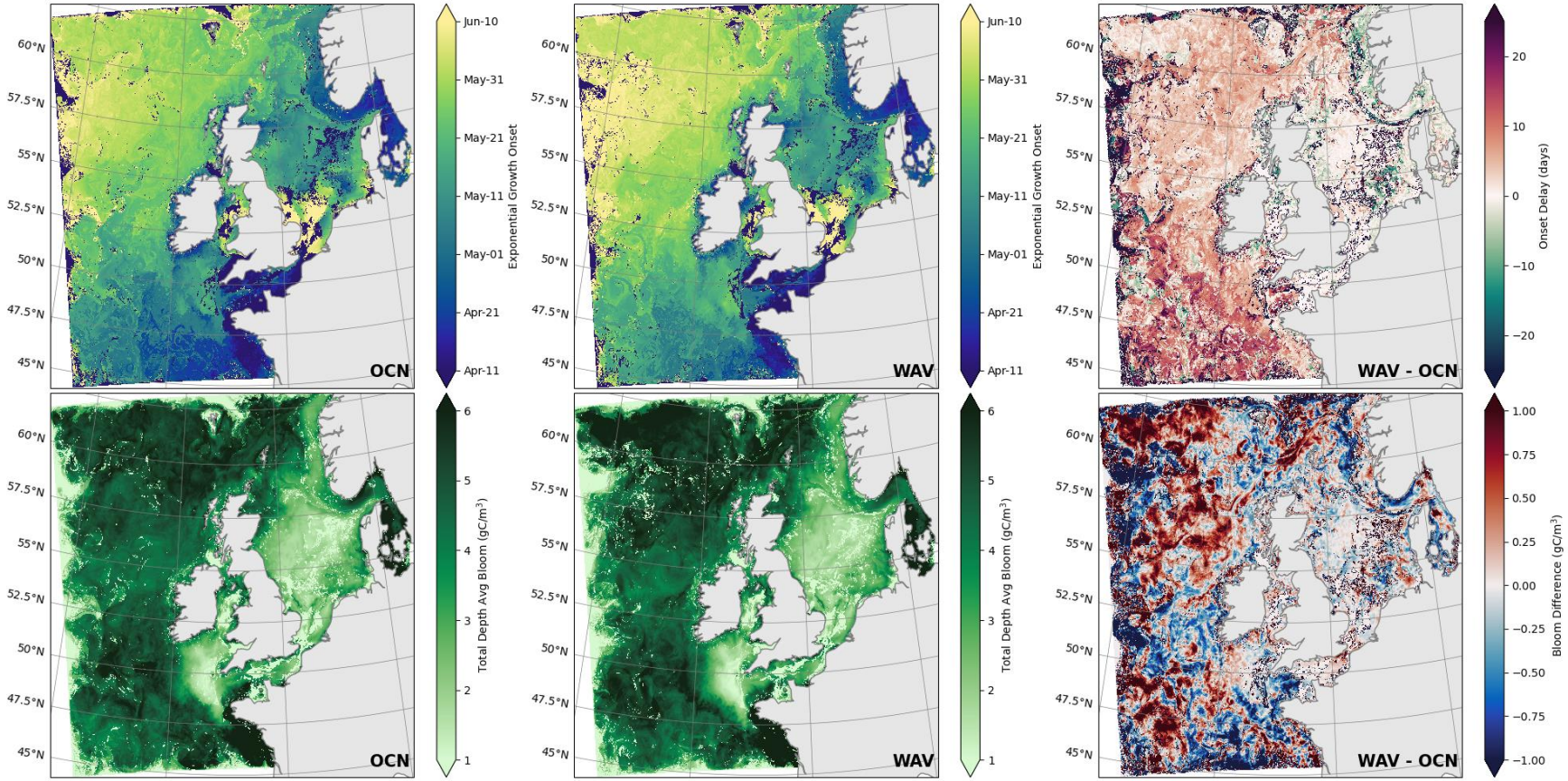


Source – Julia Rulent

Bloom Onset

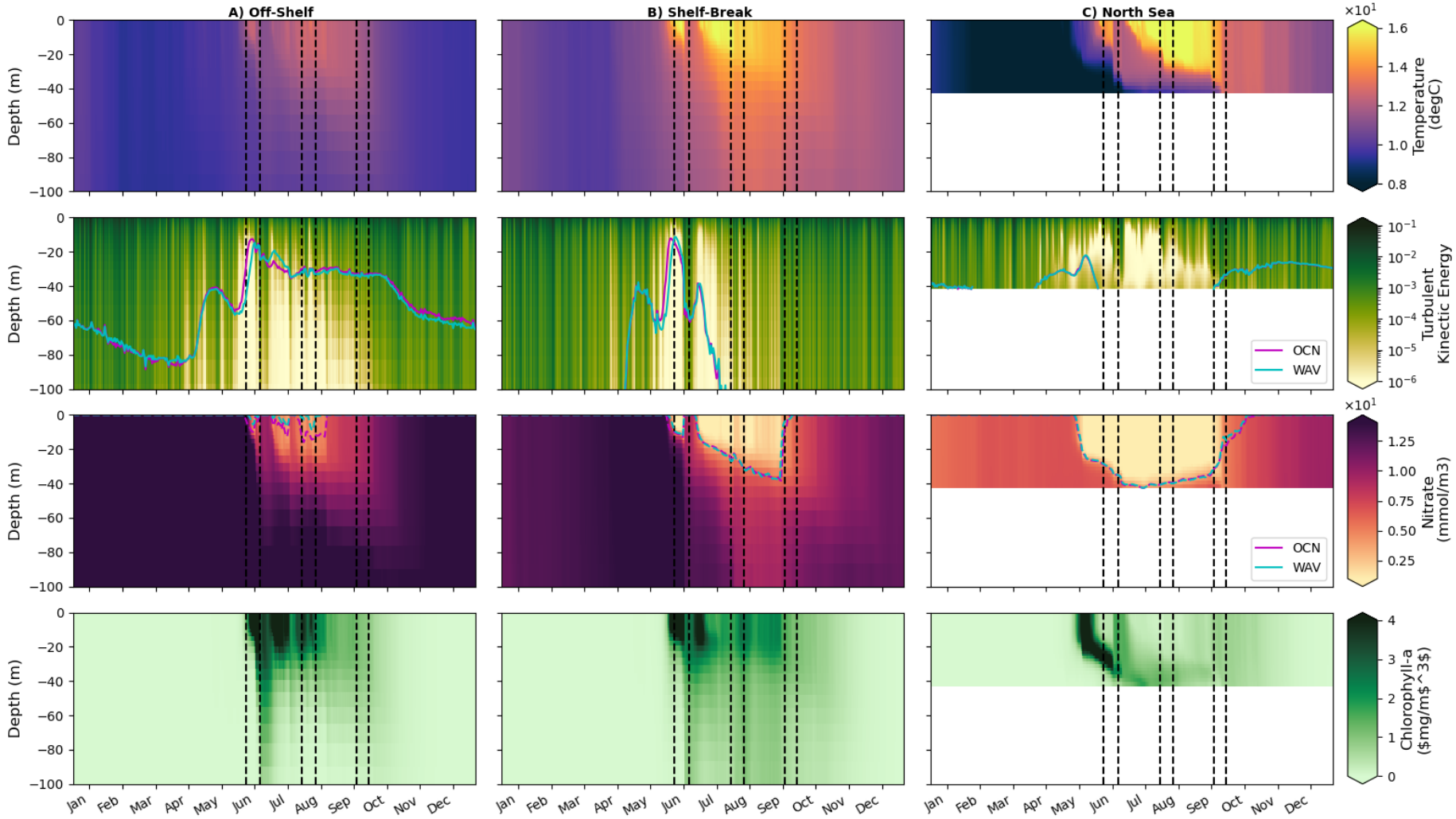
- Bloom onset defined as start of exponential increase in biomass
- Models typically enter bloom state much later than observations
- Addition of waves further delays onset by 1-2 weeks
- Waves reduced overall bloom in the south, increased in the north
- Impact significantly greater off-shelf





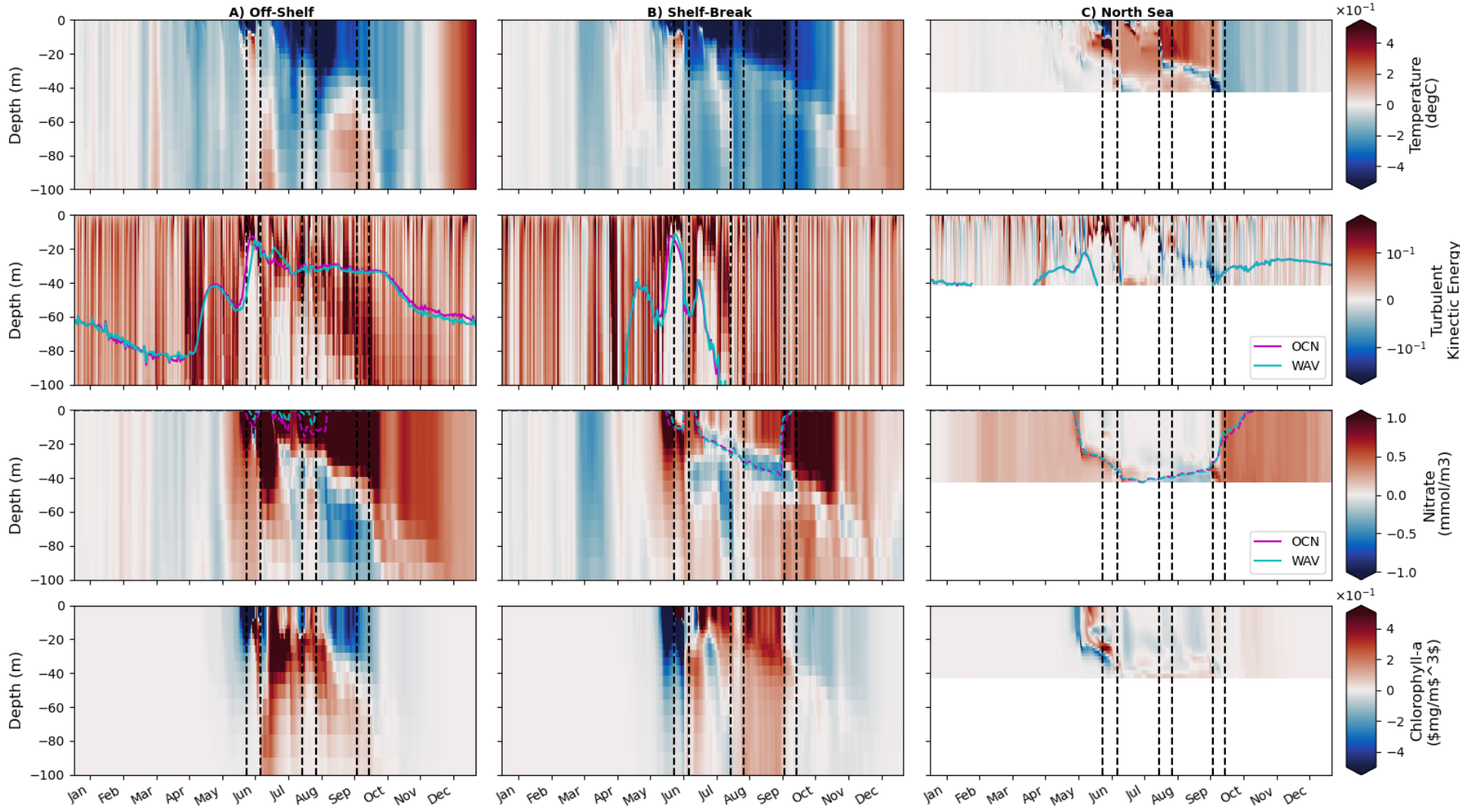
Depth Impact

- Output from model with wave coupling for three regions
- High TKE brings more nutrients up from rich, deeper layers
- Nitrate anti-correlated with chlorophyll-a
- Clear imprint from storms – nutrients increased near the surface, chlorophyll-a spread vertically
- On shelf stratification and deep chlorophyll-a maximum eroded due to storms



Depth Impact

- Difference between runs with and without waves
- Wave coupled system cooler in mixed layer due to increased vertical mixing
- Increase in turbulent kinetic energy off-shelf
- Slight deepening of euphotic depth (1% light level)
- Delay in initial bloom
- Increase below euphotic zone due to mixing

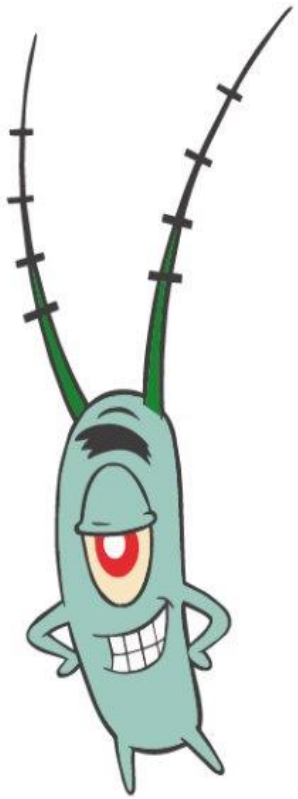


Conclusion

- First implementation of coupled ocean-wave-biogeochemistry system – yielding insights into complex interactions
- During bloom onset, enhanced wave activity suppresses blooms, causing a delay.
- Once bloom initiated, wave mixing brings nutrients up from deeper layers
- Storms have a significant impact by increasing the above features, and breaking down stratification quickly

Future Plans

- Include a coupled atmosphere model – several feedbacks not currently represented
- Investigate if BGC needs to be reparameterised when coupling
- Consider feedbacks from BGC to physical components



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Impact of waves on phytoplankton activity on the Northwest European Shelf: insights from observations and km-scale coupled models
Partridge et al. (in prep)